Soil Erosion and Sediment Transport Modeling of Hydrologic Scenarios for the Actinide Migration Evaluation at the Rocky Flats Environmental Technology Site

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Rocky Flats Environmental Technology Site
Golden, Colorado 80402

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TABLE OF CONTENTS

3

4

LIST OF TABLES

PAGE

5

LIST OF FIGURES

(All Figures at End of Document)

6

LIST OF FIGURES
(Continued)

LIST OF PLATES
(All Plates Follow the Figures at End of Document)

7

LIST OF APPENDICES

8

LIST OF ACRONYMS

Am-241	americium-241
AME	Actinide Migration Evaluation
ARS	Agricultural Research Service
ASAE	American Society of Agricultural Engineers
CDPHE	Colorado Department of Public Health and the Environment
CLIGEN	Climate generator component of WEPP
cm	centimeters
COE	U.S. Army Corp of Engineers
CSM	Colorado School of Mines
CSU	Colorado State University
CUHP	Colorado Urban Hydrograph Procedure
DEM	Digital Evaluation Model
DOE	Department of Energy
DQO	data quality objective
EMSP	U.S. Department of Energy Environmental Management Science Program
ft	foot/feet
ft^2	foot/feet squared
ft/sec	feet per second
FY	fiscal year
g	grams
g/cm^3	grams per centimeter cubed
GIS	Geographic Information System
ha	hectares
HEC-6	Hydrologic Efficiency Code 6
HEC-6T	Sedimentation in Stream Networks Model
IA	Industrial Area
IDLH	immediate danger to life and health
IM/IRA	interim measure/interim remedial action
in	inches

9

LIST OF ACRONYMS
(Continued)

km	kilometers
km^2	square kilometers
kg	kilograms
kg/m^2	kilograms per square meter
KH	Kaiser-Hill
L	liter
LANL	Los Alamos National Laboratory
lb	pounds
lb/ft^2	pounds per square foot
lb/m^2	pounds per square meter
lb/y^2	pounds per square yard
LCDB	Land Configuration Design Basis
m	meters
m^2	square meters
m^3	cubic meters
MBH	Mobile Boundary Hydraulics
m/sec	meters per second
mg/L	milligram per liter
mi	miles
mi^2	square miles
MK	Morrison Knudson
mm	millimeters
OFE	Overland Flow Element

10

LIST OF ACRONYMS
(Continued)

pCi	picocuries
pCi/g	picocuries per gram
pCi/L	picocuries per liter
POC	Point of Compliance
POE	Point of Evaluation
Pu-239/240	plutonium-239,240
RFCA	Rocky Flats Cleanup Agreement
RFCAB	Rocky Flats Citizens Advisory Board
RFETS	Rocky Flats Environmental Technology Site
RMRS	Rocky Mountain Remediation Services
SCS	Soil Conservation Service
SEP	Solar Evaporation Pond
SID	South Interceptor Ditch
Site	Rocky Flats Environmental Technology Site
T/ha	metric ton per hectare
TSS	Total Suspended Solids
U	uranium isotopes
USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WEPP	Watershed Erosion Prediction Project
WWE	Wright Water Engineers, Inc.
yr	year

11

SOIL EROSION AND SEDIMENT TRANSPORT MODELING OF HYDROLOGIC SCENARIOS FOR THE ACTINIDE MIGRATION EVALUATIONS AT THE ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

EXECUTIVE SUMMARY

The surface soils over portions of the Rocky Flats Environmental Technology Site (Site) were contaminated by accidental releases of radionuclides (actinides) including plutonium-239,240 (Pu-239/240 or Pu) and americium-241 (Am-241 or Am). The Pu-239/240 and Am-241 are strongly associated with the soil particles and do not dissociate significantly from the solid phase in water. Remediation of the actinide-contaminated soils is planned prior to Site regulatory closure. At that time, the soils must be clean enough so that when they are eroded and transported into streams and ponds, the surface-water Pu-239/240 and Am-241 concentrations will not exceed surface-water quality Action Levels. Understanding the processes and variables that contribute to and control soil erosion is important to achieving a final remedial design that limits erosion, sediment transport, and associated migration of any residual actinide contamination.

The models developed for the 2000 Report are tools for making informed decisions regarding remedial actions for actinide-contaminated soils at the Site. These tools are also used to evaluate combinations of soil remediation, erosion controls, hydrologic modifications, land uses, and other management alternatives for controlling Pu-239/240 and Am-241 migration via the soil erosion and sediment transport pathway. Additional scenarios may be modeled to evaluate land and hydrologic configuration alternatives for regulatory closure.

The Site's Actinide Migration Evaluation Project (AME) is focused on understanding actinide mobility in the environment. In 2000, the AME completed a study to estimate the impacts of soil erosion and sediment transport on Site surface water quality (hereafter referred to as the 2000 Report). The final 2000 Report is available to the public and referenced frequently herein. This study uses the AME erosion and sediment transport modeling tools to evaluate how changes to

12

the Site land surface and hydrologic features can affect surface-water concentrations of actinides. Specifically, the scenarios evaluated herein are:

- Road re-vegetation options
- Range fire effects
- Industrial area reconfiguration
- Hydrologic modifications (changes to streams and ponds)

Actinide concentrations are predicted for a variety of storm events, ranging from common storms to large floods. The models developed in 2000 have been improved per the suggestions of community stakeholders and their consultants. Data collected in fiscal year 2001 (FY01) are used to refine the models and reduce uncertainty in the predicted actinide concentrations. This report contains Errata for the 2000 Report in Appendix C.

The following conclusions are derived from the analysis presented in this report:

1. The 2000 Report showed that improved gravel and dirt roads in the Site Buffer Zone are prone to severe erosion and contribute large amounts of sediment to the streams. This report estimates that re-vegetation of the roads will reduce sediment and associated actinide contribution to the streams. Addition of topsoil to contaminated roads was shown to provide an additional benefit to surface-water quality by shielding contaminated soil from erosion and thus reducing overland transport of actinides to the streams.

2. Channel erosion (a.k.a. scour) accounts for a majority of the sediment transport at low flow. Conversely, sediment contribution from hillslopes constitutes most of the sediment yield at high flow (i.e. flood events). Therefore, actinide source terms for low flows would be expected to be stream channel sediments. Contribution of actinides from the hillslopes becomes more important for larger storms, which transport contaminated soil from source areas to the streams.

13

3. A range fire in the area with the most contaminated soil (a.k.a. 903 Pad and Lip) would increase actinide concentrations in the South Interceptor Ditch (SID) by as much as 50 percent. The maximum predicted SID surface-water concentration is about 35 picocuries per Liter (pCi/L) for a 100-year flood event occurring immediately after a fire in the most contaminated areas. Actinide mobility and yield increase with increasing burned drainage area. However, in the area modeled there is not a correlation between the extent of area burned and actinide concentrations in the surface water. For this site-specific study, extent of area burned and actinide concentrations in the stream were not correlated, but they might be under other scenarios or in other parts of the Site. The model results show that the impact of a range fire on surface-water concentrations depends on both the extent and location of the fire.

4. The AME assisted with erosion and sediment transport modeling of Industrial Area re-vegetation as part of the Kaiser-Hill Land Configuration Design Basis project. The model predicts actinide concentrations for a 100-year event to increase slightly in Walnut Creek after Industrial Area re-vegetation. Reclamation of the Industrial Area will reduce Industrial Area runoff, which currently provides some dilution of actinide concentrations in Walnut Creek. Removal of roads and roadside ditches will allow runoff from areas with residual actinide soil contamination to drain directly to the surface water, which could also increase actinide concentrations.

5. Site detention ponds are known to trap contaminated sediments and cleanse surface water by gravitational settling. Removal of the ponds will result in increased sediment and actinide concentrations for large storms. The model predicts that Ponds A-4, B-5, and C-1 benefit water quality by reducing sediment and actinide yields and concentrations by as much as 44 percent. By comparison, the non-terminal ponds A-1, A-2, B-1, B-2, B-3, and B-4 provide a smaller amount of sediment and actinide settling.

6. Routing the upper one-third of the SID to Woman Creek via an engineered channel was evaluated because most of the water tributary to the SID is relatively clean runoff from impervious industrialized areas. This alternative was found to increase actinide

concentrations in the SID and in Woman Creek. However, this scenario resulted in greatly reduced runoff, sediment, and actinide yields to Pond C-2, which could reduce management resources dedicated to Pond C-2.

1.0 INTRODUCTION

1.1 Purpose

This report presents results of the Actinide Migration Evaluation (AME) Soil Erosion and Sediment Transport Modeling Project activities for Fiscal Year 2001 (FY01); a continuation of the work presented in the 2000 report: *Report on Soil Erosion and Surface Water Sediment Transport Modeling for the Actinide Migration Evaluation at the Rocky Flats Environmental Technology Site* (Kaiser-Hill Company, L.L.C. [Kaiser-Hill]/Rocky Mountain Remediation Services [RMRC], August 2000, a.k.a. 2000 Report). Extensive discussion of the erosion and sediment transport model calibration procedures and the results obtained in 2000 is presented in the Appendix A CD-ROM. The 2000 Report results were used to draw conclusions about how soil erosion and sediment transport could affect Site water quality for current conditions and for selected soil remediation action levels. This 2002 report contains an erratum for the 2000 Report in Appendix B, complete with new figures that can be substituted into the 2000 Report.

The models developed for the 2000 Report are tools for making informed decisions regarding remedial actions for actinide-contaminated soils at the Site. These tools are also used to evaluate combinations of soil remediation, erosion controls, hydrologic modifications, land uses, and other management alternatives for controlling Pu-239/240 and Am-241 migration via the soil erosion and sediment transport pathway. Additional scenarios may be modeled to evaluate land and hydrologic configuration alternatives for regulatory closure.

The AME is investigating the mobility of plutonium-239/240 (Pu-239/240), americium-241 (Am-241), and uranium-234, 235, 238 (U) isotopes in the Site environment in preparation of regulatory closure. A variety of scenarios, which simulate potential components of the Site end-state configuration and management issues, were modeled. Potential configurations of Site watersheds, natural disasters (i.e. range fires and floods), and land management practices were evaluated to determine their impact on actinide concentrations in streams. Figure 1 is a map of the Site showing its principal watershed boundaries.

The transport of soil by erosion and overland flow is modeled using the Watershed Erosion Prediction Project (WEPP) model (Flanagan and Livingston 1995). The transport of sediments by surface water within Site drainage channels is estimated with the Sedimentation in Stream Networks (HEC-6T) model (Thomas 1999). These two models are used in tandem to provide input to a spreadsheet model that is used to calculate surface-water actinide concentrations (Figure 2).

The U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS), the U.S. Department of Interior, and other cooperators developed the WEPP model. It is a part of a new generation of process-oriented computer models, which incorporate improvements in erosion prediction technology based on erosion mechanics, soil physics, plant science, hydrology, infiltration theory, and stochastic weather generation (Flanagan and Livingston, 1995). The WEPP model is a distributed parameter, continuous simulation computer program that estimates spatial and temporal distributions of soil loss and sediment deposition from overland flow on hillslopes. Extensive model validation has been done by ARS and other cooperators (Laflen et al., 1994, Zhang et al., 1996; Flanagan and Livingston, 1995; Liu, et al., 1997; and Baffaut et al., 1998).

The HEC-6T model is a recently updated version of the HEC-6 model originally developed by the United States Army Corps of Engineers (COE). HEC-6T combines flow computation via the Manning Equation with sediment suspension and deposition via 15 different user-selected methods. For this study, Yang's equation was selected based on the advice of Dr. Pierre Julien (Colorado State University [CSU]) and Ernie Pemberton, P.E. (WWE)—both recognized experts in sedimentation. The model has been used to estimate sediment transport characteristics in rivers largely for the purpose of engineering design and maintenance of waterways and dams. It can also be used for estimating contaminant yields in streams, provided that the contaminant is associated with the sediment phase.

The goal of the AME is to achieve the objectives contained in the AME Data Quality Objectives (DQO) document (Kaiser-Hill 2000b). Specifically, the goals of the AME are to answer the following questions in the order of urgency shown:

- **Urgent**: What are the important actinide migration sources and migration processes that account for elevated surface water quality measurements?

- **Near-term**: What will be the impacts of actinide migration on planned remedial actions? To what level do sources need to be cleaned up to protect surface water from exceeding action levels for actinides? What effect do the planned remedial actions have on actinide migration?

- **Long-term**: How will actinide migration affect surface water and air quality after Site closure (or what soil action levels will be sufficiently protective of surface water over the long-term)?

- **Long-term**: What is the long-term actinide migration, and will it impact downstream areas (e.g. accumulation)?

These objectives are addressed by performing mathematical modeling of the actinide transport processes in the Site environment.

1.2 Regulatory Framework

Surface water standards and action levels are established in the Rocky Flats Cleanup Agreement (DOE 1996a). Surface water monitoring at the Site is performed in accordance in the Integrated Monitoring Plan (IMP) (Kaiser-Hill 1999) and the Industrial Area Interim Measures/ Interim Remedial Action Decision Document (IA IM/IRA) (EG&G 1994).

RFCA provides an Action Level Framework (ALF) for Point of Evaluation (POE) monitoring and specific standards for Point of Compliance (POC) monitoring. POE monitoring is performed within Segment 5 of the Big Dry Creek Basin (i.e. segmentation per the Clean Water Act), which includes the terminal ponds, the main stream channels of North and South Walnut Creek, Pond C-2, and the SID (Figure 3). POC monitoring is performed within Segment 4 of the Big Dry Creek Basin, which includes Walnut and Woman Creeks below the terminal ponds (Figure 3). All sampling at POEs and POCs is continuous, flow-paced composite sampling.

18

Evaluation of radionuclide activity data collected from POE and POC monitoring locations is currently performed using 30-day volume-weighted moving averaging. The 30-day average for a particular day at a given location is calculated using a 'window' of time which extends back over the previous 30 days for which both flow and measurement of activity occurred. These 30-day averages are compared to appropriate action levels and standards and reported according to the requirements of the IMP and RFCA.

1.3 Scope

The Conceptual Model for the AME at the Rocky Flats Environmental Technology Site (RFETS or Site) (Kaiser-Hill 1998a) discusses potential pathways for actinide migration in the environment and their relative importance based on current information. The physical transport of Pu-239/240 and Am-241 by the processes of erosion, overland flow, and channel flow is a dominant migration pathway. Research supported by the AME has shown that Pu-239/240 and Am-241 are predominantly transported in surface water on suspended solids (Santschi et al. 1999). Table 1 lists technical terms commonly used in this report to discuss the surface-water transport pathway.

The WEPP model was used to estimate the runoff and sediment yields from Site hillslopes and to estimate runoff and sediment loading to channels within the SID, Walnut Creek and Woman Creek watersheds. The WEPP sediment and runoff output was then input to the HEC-6T model to estimate stream flow and sediment transport.

The combined output of the WEPP and HEC-6T models was used to identify surface water concentrations, sources, and sinks for Pu-239/240 and Am-241 in the watersheds using spreadsheet models that compute surface-water concentrations for the actinides. The spreadsheet models are called "Actinide Transport Models."

This report provides the Pu-239/240 and Am-241 surface water transport modeling results, including:

- Descriptions of the three drainages that were modeled: Woman Creek, the SID, and Walnut Creek (Section 2)

- A description of field data collected in FY01 and model refinements that were made to better estimate Pu-239/240 and Am-241 transport, especially related to streambed sediment re-suspension (a.k.a. channel erosion)

- Updated results of hillslope erosion modeling for the SID watershed, including predicted rates of movement for Pu-239/240 and Am-241 in surface soils

- The effects of road re-vegetation on surface water concentrations of Pu-239/240 and Am-241

- The effects of range fires on surface water concentrations of Pu-239/240 and Am-241 in the SID watershed

- The effects of IA re-vegetation on surface water concentrations of Pu-239/240 and Am-241

- The effects of pond and stream reconfiguration options on surface water concentrations of Pu-239/240 and Am-241

- Erosion and actinide mobility maps

- A description of the WEPP model calibration process for modeling range fire effects (Appendix A)

- A CD-ROM with model input and output data and other Site data (Appendix A)

1.4 Uncertainties

Natural physical systems are typically highly complex and often contain components that are not completely understood or measurable. Any model of a natural system must make simplifying assumptions to reduce the level of complexity, account for knowledge gaps, and to offer a solution that is feasible given available technology and resources.

Computer models used for this project rely on underlying conceptual models of physical processes, mathematical algorithms that attempt to replicate these processes and measurements or input data for the models. Uncertainty associated with modeling results can be attributed to three general sources: 1) structural uncertainty, 2) input uncertainty, and 3) parameter uncertainty.

Structural uncertainty relates to the degree to which the models accurately and completely represent the physical system being analyzed. Input uncertainty reflects the spatial and temporal variability of the input data along with measurement errors. Parameter uncertainty refers to the uncertainty associated with internal model parameters, which are fixed and not usually adjusted or available for adjustment by the user. These three categories of uncertainty, as they pertain specifically to this erosion, sediment and actinide transport modeling project, are discussed in detail in Appendix D of the 2000 Report (Kaiser-Hill/Rocky Mountain Remediation Services [KH/RMRS] 2000) included in the CD-ROM in Appendix A.

1.5 Future Scope and Refinements

The models are being used to provide information for the final configuration of the Site. The Land Configuration Design Basis (LCDB) project is using these modeling tools to evaluate alternative configurations and test the adequacy of conceptual designs for the future Site land surface. Preliminary work products developed for Scenario 0 or "baseline scenario" for the LCDB project are presented herein.

21

2.0 STUDY AREA AND CLIMATE

Three drainage basins collect surface water at the Site (Figure 1). The basins are drained by natural, intermittent to ephemeral, and perennial streams that generally flow from west to east. The northwest portion of the Site is drained by Rock Creek, which flows into Coal Creek east of the Site. This drainage is not considered in the study, since it has not been affected by Site activities. Walnut Creek drains the northeast quadrant of the Site. The SID runs west to east between the south edge of the IA and Woman Creek and collects runoff from the IA and the Buffer Zone, including the 903 Pad Area. Woman Creek collects water from west of the Site and from the southern portion of the Site. The drainage area of both watersheds, described below, is included in the soil erosion and surface water sediment transport modeling.

2.1 Woman Creek

The on-Site portion of the Woman Creek watershed is approximately 8 square kilometers (km^2) (3.1 square miles [mi^2]). Two branches to the west, known as North Woman Creek and South Woman Creek, form Woman Creek. These branches converge about 1,800 feet east of the western Site boundary (Figure 1). The flow in Woman Creek is intermittent. There are two detention ponds in the Woman Creek drainage: 1) Pond C-1, which is located within the stream channel and is currently configured for continuous flow-through operation; and 2) Pond C-2, which is off-channel and used to collect runoff from the south side of the IA, the 881 Hillside, and the 903 Pad Area via the SID. Pond C-2 is batch discharged, typically once a year, to Woman Creek. In the past, the majority of water from Woman Creek was diverted into Mower Ditch. The diversion was shut off in 1997, and now water flows off-Site in the natural Woman Creek channel to the Woman Creek Reservoir on the east side of Indiana Street.

Antelope Springs Gulch is a perennial feature that carries water from Antelope Springs, a large seep to the south of Woman Creek. It normally has base flow throughout the year. Antelope Springs Gulch flows into Woman Creek just upstream of Pond C-1.

22

The SID was constructed in 1980 to divert surface water runoff from the southern portion of the IA to Pond C-2 (Figure 1). It was originally designed to handle a 100-year precipitation event. Erosion, sedimentation, and encroachment of vegetation have reduced the flow velocity in the SID and the hydraulic capacity of the SID (EG&G 1992a). The SID was modeled as a separate drainage, because its flow is entirely contained by Pond C-2.

2.2 Walnut Creek

The Walnut Creek watershed area is approximately 3.7 mi^2 (9.6 square km^2) (Figure 1). The watershed is comprised of two perennial streams (South Walnut Creek and North Walnut Creek) and is ephemeral to intermittent features known as No Name Gulch and the McKay Bypass Canal. The Present Landfill and the Landfill Pond are situated in the headwaters of No Name Gulch. The Landfill Pond does not discharge into the gulch. Flows in No Name Gulch result primarily from base flow and runoff from surrounding hillsides.

Water in the upper reaches of North Walnut Creek (northwest of the IA) is diverted to the McKay Bypass, which flows to the north of the Present Landfill. Until 1999, this water reentered the Walnut Creek drainage downstream of No Name Gulch. A diversion structure and pipeline were installed to route water to Great Western Reservoir, precluding flow from Walnut Creek. This diversion, which was absent in the 2000 models, was added to the models for this study. Water draining from the north side of the IA enters North Walnut Creek and is diverted by pipeline around Ponds A-1 and A-2 into A-3. Ponds A-1 and A-2 are used for spill control for the IA and do not discharge into the drainage. Pond A-3 is batch released to Pond A-4, which is batch discharged into the North Walnut Creek channel.

South Walnut Creek receives runoff from the IA, including the Central Avenue Ditch and a portion of the 903 Pad Area. The natural channel of South Walnut Creek has been greatly changed by construction in the IA during operation of the Site and the B-Series Detention Ponds in 1980 (Figure 1). Ponds B-1 and B-2 are normally off-line but are maintained at a level to keep sediments wet and are reserved for IA spill control. Water in Pond B-3 is batch discharged to B-

4, then flows through to B-5, which is then batch discharged to South Walnut Creek. A gate valve and stand pipe were installed in Pond B-5 in 1998 to allow for direct batch releases.

The soil erosion and surface water transport modeling study includes all areas drained by the Woman Creek (including the SID) and Walnut Creek watersheds. The study area is limited to the Site property, except for a small area of grazed land on the upper reaches of Woman Creek.

2.3 Climate

The Site's climate is semi-arid, with an annual average precipitation of 368 millimeters (mm) (14.5 inches [in]), about 50 percent of which occurs as rain in early spring and late summer (DOE 1995a). Evapotranspiration averages over 400 mm (15.8 in) per year, creating a water deficit in most years (Wright Water Engineers [WWE] 1995). Much of the runoff feeding the Site drainages occurs rapidly, originating from the mainly impervious IA surfaces (RMRS 1998b). Buffer Zone runoff from small to intermediate events occurs chiefly on roads, steep hillslopes, and areas where culverts feed IA runoff to the Buffer Zone. Precipitation events greater than about 12.7 mm (0.5 in) per 24 hours produce runoff in some areas (EG&G 1993a and 1993b).

3.0 CONCEPTUAL MODEL FOR SURFACE WATER TRANSPORT OF ACTINIDES

A Site conceptual model was developed to provide a qualitative understanding of Pu-239/240 and Am-241 sources and transport pathways for the Walnut and Woman Creek watersheds and a framework for quantifying transport rates of actinides for Site environmental conditions (Kaiser-Hill 1998a). Pu-239/240 and Am-241 are tightly adsorbed to soil particulates, with up to 90 percent retained in the upper 15 centimeters (cm) of the soil profile (Webb et al., 1997; Litaor et al. 1996; Webb 1992; Choppin 1992; and Watters et al. 1983). The Pu-239/240 and Am-241 present in the surface soil can be transported with associated particulates by overland flow to surface water channels.

The major processes that cause the transport of soil particulates to surface water channels are hillslope erosion from overland flow. Channel flow then transports the eroded sediments downstream. Contaminant transport by overland flow can be by both physical and chemical mechanisms. Physical processes dominate the transport of Pu-239/240 and Am-241 by overland flow for the reasons mentioned above. The AME focuses on the physical transport processes using mathematical transport models for the air and surface-water pathways. The AME air transport modeling team was consulted to determine the appropriate extent of the range fire boundaries for modeling purposes. The range fire scenarios for the air modeling and erosion/sediment transport modeling efforts are constrained by similar boundaries.

The 2000 Report contains a detailed discussion on hillslope erosion, overland flow and channeled flow processes. A discussion of the hillslope erosion (WEPP) and sediment transport model (HEC-6T) selection process is also presented therein. This report will focus on discussion of model improvements and results for the modeled scenarios.

25

4.0 DESCRIPTION OF THE MODELS

Two models were used for this evaluation: 1) the site WEPP erosion model; and 2) the HEC-6T model. These models, along with the assumptions used, are discussed in the following sections. Section 5.0 describes how these two models were integrated.

4.1 Site Model Structure for WEPP Simulations

The Site WEPP erosion model is separated into three watersheds: 1) Woman Creek; 2) the SID; and 3) Walnut Creek. Each watershed has been divided into hillslopes based on drainage patterns (Figure 4).

Each hillslope is divided into overland flow elements (OFEs) that are distinguished by specific soil and vegetative cover characteristics. OFE boundaries were determined by boundaries between different soil groups based on the Site soil map and/or by changes in vegetation type based on the Site's vegetation map. Soil and vegetation parameters used in the model are discussed in detail in the CD-ROM in Appendix A.

The slopes, lengths, and areas of each OFE were determined using geographic information systems (GIS). The WEPP hillslopes are two-dimensional surfaces that vary in length and width and along the vertical dimension (the slope) but do not vary laterally across the slope. The AME project team developed techniques to convert WEPP output back into data that can be mapped using GIS to show the distribution of erosion across the watersheds. (See the CD-ROM in Appendix A of this report.)

The hillslopes were delineated to provide reasonable resolution for estimation of runoff and erosion without making the model unnecessarily complex. Some of the hillslope lengths exceed the recommended lengths for WEPP. Therefore, contributors to WEPP at the ARS Southwest Watershed Research Center in Tucson, Arizona were consulted to review the hillslope and channel delineations. Their assessment concluded that the hillslopes and channels were reasonable (J. Stone and M. Weltz, personal communication 1998). Mokhothu (1996) showed that increasing the complexity of the WEPP watershed model did not improve the accuracy of the model predictions for a small rangeland watershed.

4.2 The HEC-6T Model

HEC-6T allows for up to 100 tributary inflows to the main channel, which was crucial for modeling the Site watersheds. The model was adjusted to provide realistic estimation of hydraulic parameters, such as the stream velocity. The HEC-6T models were parameterized with field data for the channels, including the channel geometry, channel roughness, erodible sediment depth in the channel, and streambed sediment grain-size distributions.

4.3 HEC-6T Site Model Structure

Several assumptions must be made for each watershed model, based on field observations or standard engineering practices. General assumptions standard to each watershed include the following:

- Channel roughness for the stream bed, left and right banks, and left and right over-banks (looking downstream) based on field observations
- Depth of bed material available for erosion based on field measurements
- Percentage of bed area available for erosion based on field observations
- Sediment concentration in the base flow based on water monitoring data
- Tributary runoff and associated sediment concentrations from industrialized areas obtained from monitoring data and the Rocky Flats Plant Drainage and Flood Control Master Plan
- Negligible infiltration (loss) of water from the channels during the runoff period

As mentioned above, Yang's sediment transport equation was selected to simulate sediment transport processes in the HEC-6T model. Yang's equation computes total load, comprised of both suspended load and bed load. The equation contends that the rate of sediment transport in an alluvial channel is primarily governed by the rate of expenditure of potential energy per unit weight of water, i.e., the unit stream power (Yang 1996). To determine total sediment concentration, Yang considered a relation between the following relevant variables:

$$C_t,\ VS,\ V_{cr}S,\ u_*,\ \nu,\ \omega,\ d$$

Where:

C_t = total sediment concentration, with wash load excluded (in milligrams per liter [mg/L] by weight);

VS = unit stream power;

$V_{cr}S$ = critical unit stream power at incipient motion;

u_* = shear velocity;

ν = kinematic viscosity;

ω = fall velocity of sediment; and

d = median particle diameter.

Using the Buckingham π theorem, C_t can be expressed in a dimensionless form. From laboratory flume data and running multiple regression analysis, Yang found the best form of the equation to be as follows:

$$\log C_t = 5.435 - 0.286\log\frac{\omega d}{\nu} - 0.457\log\frac{u_*}{\omega} + \left(1.799 - 0.409\log\frac{\omega d}{\nu} - 0.314\log\frac{u_*}{\omega}\right)\log\left(\frac{VS}{\omega} - \frac{V_{cr}S}{\omega}\right) \tag{1}$$

Yang's equation was found to work satisfactorily both for laboratory and field data. For the FY00 study, it was assumed that the bed load component of the total yield was negligible when compared to the suspended load because field observations revealed that the streams are armored and contain small amounts of fine-grained erodible material. (See the CD-ROM in Appendix A

28

[KH/RMRS 2000 Appendix D].) However, a more extensive channel survey in September 2000 provided more detailed data for the HEC-6T models, which made estimation of channel erosion possible for the FY01 study.

5.0 INTEGRATION OF THE WEPP AND HEC-6T MODELS

The WEPP and HEC-6T models must be integrated to simulate the movement of sediment particles as they might travel from the uplands or hillslopes to the stream channel systems to the Site boundaries. Knowledge of the source, transport and fate of sediment particles is basic information required to calculate potential actinide transport within the Site and beyond its boundaries. The integrated WEPP and HEC-6T models provide the best scientific tool available to simulate soil erosion and sediment transport.

A discussion of how the WEPP and HEC-6T models have been integrated for this study is in the 2000 Report and in Chromec et al. (2000). In FY01, the AME project expanded development of an application running in Microsoft Access™ called "WEPP Tools," which harvests data from WEPP output files, stores it in a database format, and converts the data to input files for HEC-6T. The application is also planned to replace the spreadsheet Actinide Transport Models, which take the WEPP and HEC-6T output and GIS information to compute actinide concentrations in surface water.

Separate WEPP and corresponding HEC-6T models were built for the SID, Woman Creek, Mower Ditch, and Walnut Creek watersheds. The models were used to estimate sediment and associated actinide transport for six events: 1) 40.8-mm, 6-hour, 2-year return interval; 2) 31.5-mm, 2-hour, 2-year return interval; 3) 62.3-mm, 6-hour, 10-year return interval; 4) 97.1-mm, 6-hour, 100-year return interval; 5) 74.9-mm, 11.5-hour event similar to the actual May 17, 1995 event (11-year return interval); and 6) 35-mm, 11.5-hour, low intensity event, with an approximate one-year return interval.

The rainfall distributions during the 6-hour and 2-hour events were obtained from the Rocky Flats Drainage and Flood Control Master Plan (EG&G 1992b). The rainfall distributions were

29

derived from the Colorado Urban Hydrograph Procedure (CUHP). For this distribution, a majority of the rainfall occurs in the first hour of the storm. The rainfall distributions for the two 11.5-hour events were based on Site rain gage data for the May 17, 1995 event.

The storms were run in the WEPP single storm mode simulation for each Site hillslope. The runoff, peak discharge, sediment yields and particle size distribution output from WEPP was formatted for HEC-6T input. The integration of the two models is described below.

The WEPP hillslope sediment yields were modeled as tributary inflows to the main stream channels. In selected stream reaches, the runoff and sediment yields from adjacent hillslopes were added together to condense the number of tributary inflows to the channels. This made the models logistically easier to program and run while maintaining adequate representation of the natural system.

The sediment concentration and stream discharge data available for calibration of the HEC-6T model are dominated by small, one-year return period events. Only a few samples collected during non-ideal portions of the runoff hydrograph are available for a flood event that occurred on May 17, 1995. The flood damaged many sampling stations, and the automatic samplers were programmed to collect samples for a much smaller event.

5.1 Summary of AME Modeling Data Quality Objectives

The following is a summary of the DQOs that have been identified to adequately substantiate the quality of the erosion modeling effort. The DQOs identified in this summary are the categories of applicable requirements that have been excerpted from "Fiscal Year 2000 Actinide Migration Evaluation Data Quality Objectives, Revision 2." The erosion modeling effort is an important component of the overall regulatory closure of the Site and may impact action levels and remedial approaches. The modeling results will undergo intense scrutiny by the Site, stakeholders, and regulatory agencies. Therefore, the stringent application of the applicable DQOs to the erosion and sediment modeling effort is essential. The DQO categories applicable to the erosion modeling effort include sensitivity/uncertainty analysis, calibration, and verification/validation activities, which are described below.

5.1.1 Uncertainty Analysis

An assessment of the uncertainty in the modeling technique is presented in Appendix D of the 2000 Report (See CD-ROM in Appendix A herein). Estimated sediment and actinide yields and concentrations are believed to be accurate to within one order of magnitude (i.e. factor of ten). However, it is not possible to calculate the actual error due to the number of sources of uncertainty and lack of field data pertaining to the uncertainties.

5.1.2 Calibration

Model calibration is an iterative process of parameter adjustment such that model output satisfactorily estimates a set of real-world data. A calibration of the erosion model has been performed in accordance with the AME DQO criteria. A description of the erosion and sediment transport model calibration processes and comparisons of predicted values to Site monitoring observed data are found in the Appendix A CD-ROM (Appendices A and C of the 2000 Report).

5.1.3 Model Verification/Validation

The process of model verification/validation (the assessment of model adequacy) includes assessing all aspects of the model's assumptions, inputs, outputs, sensitivities, and uncertainty, with particular emphasis on calibration results and limitations. Verification/validation of the erosion model has been performed in accordance with the AME DQO criteria. A description of the verification/validation activities, including the results of comparisons to observed Site monitoring data, can be found in the Appendix A CD-ROM (Appendices A and C of the 2000 Report).

6.0 MODEL REFINEMENTS

The 2000 Report identifies assumptions and modeling techniques that could be improved to help reduce uncertainty in the predicted sediment yields and actinide concentrations. In FY01, some assumptions and techniques were evaluated and refined to make the models more representative of actual Site conditions and processes. Items needing redress in FY01 are discussed in each section below.

6.1 South Interceptor Ditch Hydraulics Improvements in HEC-6T

In the SID HEC-6T models, problems arose with simulating the hydraulic conditions associated with the rip rap energy dissipation structures (a.k.a. "drop structures") in the SID channel. Using the actual slope and geometry of the drop structures caused unrealistic predicted velocities and thus unrealistic predicted sediment transport. Therefore, a second model was developed that removed the drop structures from the channel geometry, and this second model predicted more realistic surface-water velocities. Both models were run. The range of predicted sediment yields and associated actinide concentrations were reported in the 2000 Report.

The reported values for predicted sediment yields and concentrations in the SID was thought to be arbitrary and perhaps not representative of actual conditions by some reviewers of the 2000 Report. Therefore, the AME created a third model in FY01 in an attempt to treat the drop structures in a more realistic way. The drop structures are comprised of piles of large, angular pieces of granite rock with a mean diameter about 0.5 m. Even during high flow events, most, if not all, of the water in the SID flows through these structures; not over them. Therefore, the new FY01 HEC-6T models use drop-structure cross-sections shaped like angular protrusions resembling serrated teeth of a saw. Three, slightly offset serrated cross sections are programmed in series for each drop structure. This cross section geometry was designed to be more representative of the rip rap structures. Figure 5 shows a comparison of selected SID FY00 and FY01 model cross-section geometry.

32

The hydraulic conditions associated with the serrated drop-structure model were evaluated by examining the surface-water velocities predicted by HEC-6T. For large events such as the 100-year flood, and perhaps the 10-year flood, a substantial amount of flow would be expected to cascade over the drop structures (i.e. critical flow). However, for smaller events, much lower velocities would be expected. According to the U.S. Bureau of Reclamation (USBR) Water Measurement Manual (USBR 1997), a velocity of about 5.8 meters per second (m/sec) (19 feet per second [ft/sec]) is measurable with a current meter. This limit was kept in mind when evaluating the HEC-6T estimated velocities for reasonableness. Figure 6 shows comparisons of estimated flow velocities obtained for selected SID HEC-6T models. The velocities predicted by the FY01 model on the drop structures are typically less than 3 m/sec (about 10 ft/sec), and maximum velocities observed at the end of the SID approach 5 m/sec (about 15 ft/sec). These velocities were determined to be realistic based on comparison with the USBR data.

A series of sensitivity analyses were done to ensure that the serrated drop-structure model performed in a manner consistent with expectations. The Manning's n-value, which is the channel roughness coefficient, predominantly controls the surface-water flow velocity and thus the suspended sediment transport in HEC-6T. Figure 7 shows how the predicted sediment yield is influenced by the Manning's n-value selection. The data in Figure 7 generally plot as expected with less sediment transport predicted for higher Manning's n-values.

These model settings were obtained from Dr. Evan Canfield (personal communication, 2001) with the Agricultural Research Service (ARS). Dr. Canfield is a member of the Los Alamos modeling team, which is conducting a similar study for the streams at Los Alamos.

The serrated drop-structure model was determined to be more representative of the hydraulic conditions in the SID, and it was used exclusively to estimate sediment and actinide transport for the FY01 results. Table 2 shows that the serrated drop structure model sediment yields are much larger than the yields predicted in FY00 due to the inclusion of channel erosion and re-suspension. The predicted sediment yields for the SID appear to be a realistic extension of the available monitoring data, which were collected for small storms, but the models appear to over-estimate sediment and actinide yields and concentrations by an order of magnitude.

6.2 Streambed Sediment Field Inventory

Several peer reviewers of the FY00 work, including AME peer reviewer Dr. Leonard Lane (ARS, Tucson, AZ) and Rocky Flats Citizens Advisory Board (RFCAB) peer reviewer Dr. Tom Hakonson (CSU), commented that the channel erosion component of HEC-6T should be further evaluated and that data for channel erodibility should be collected. In response to these suggestions, the AME conducted a streambed survey and evaluated streambed erosion in September 2000 for all of the channels represented in the sediment transport models. AME personnel walked each of the channels depicted in the HEC-6T models. Observations were made in the field to estimate and/or describe:

- The percentage of the streambed available for erosion
- The depth of erodible streambed sediment
- The estimated Manning's n-value (channel roughness coefficient) for the stream banks and the streambed
- The types of streambed armoring, erosion features such as head cuts
- Any other observed channel characteristics relevant to the HEC-6T models

The streambed characteristics were generalized into a stream channel classification system whereby channel types (e.g. Type 1, 2, 3, etc.) were assigned estimated quantitative values for the five items listed above. The stream segments were classified by channel type in the field. The channel classification system is described in the legends of Plates 1 through 5 (in pockets) which show the channel data for the Site stream segments in the models.

Streambed sediment samples were collected for particle-size distribution analysis; Pu and Am content; and field bulk density measurement. The Pu and Am data were averaged for individual stream segments and mapped on Figure 8. Photographs of the streambeds and channels and the particle size distribution data are shown in Plates 1 through 5.

The streambed data were used to compare the sediment Pu and Am activities to the hillslope activities. The sediment and hillslope activities provided direction on how to model the streambed erosion component of the actinide transport. Inspection of the Pu and Am data reveal the sediments have less activity than the hillslope soils in adjacent contaminated areas. The reduced activity is likely a result of the channel sediment, hillslope material and eroded channel bank mixture. The bank mixture has a notably lower activity. The actinide transport models were run such that the material re-suspended (eroded) from the channel has the same activity as the hillslope material to simplify the models, limit their uncertainty, and provide a measure of conservatism in estimating actinide concentrations in surface water. Therefore, the actinide transport from channel erosion is overestimated. A range of actinide concentration values is shown to provide a range of estimated actinide concentrations and a relative measure of uncertainty. The measured sediment actinide concentration data were initially intended to be used to estimate actinide re-suspension from the streambed (Plates 1-5). However, it was determined that this protocol made the models unnecessarily complex. Therefore, the measured data were used qualitatively to evaluate the re-suspended activity predicted by the models.

The average actinide concentrations are derived from models run: 1) with channel erosion, and 2) without channel erosion. In addition, a range of actinide concentration values (with and without channel erosion) is also shown to provide a range of uncertainty. The mean and range of actinide concentration values are reported herein.

Other HEC-6T parameters were evaluated to optimize their effect on predicted sediment transport. As stated in the 2000 Report, the HEC-6T streambed erosion module is also affected by:

- Streambed Erodible Depth (set to 3 mm to 305 mm)
- Percentage of Streambed Area Available for Erosion (set to 1 to 100 percent)

These two parameters were distributed along the streambeds in the HEC-6T models per the observations made in the streambed sediment field inventory (Section 6.2). HEC-6T input parameters that were found to have minor effects on the predicted streambed erosion are:

35

- Streambed Erosion Shear Stress (set between 0.5 and 1.5 kg/m^2 [0.1- 0.3 lb/ft^2])
- Sediment Depositional Shear Stress (set to 2.9 kg/m^2 [0.6 lb/ft^2])

Other HEC-6T input parameters found to have a significant influence on the predicted streambed erosion and transport of clay and silt particles are:

- Shear Stress Threshold for Clay and Silt Deposition (set to 0.020 kg/m^2 [0.004 lb/ft^2])
- Shear Stress Threshold for Erosion of Clay and Silt (set to 0.012 kg/m^2 [0.0024 lb/ft^2])
- Shear Stress Threshold for Mass Erosion (set to 0.073 kg/m^2 [0.015 lb/ft^2])
- Erosion Rate for Clay and Silt (set to 0.005 kg/m^2 [0.001 lb/ft^2])
- Deposition Threshold for Silt (set to 0.007 kg/m^2 [0.0015 lb/ft^2])
- Slope of the Erosion Rate Curve for Mass Erosion (set to 30)

Sensitivity analyses were not performed on the shear stress thresholds for clay, silt, and sand erosion and deposition. These values were obtained through consultation with Dr. Evan Canfield, whose study at Los Alamos National Laboratory (LANL) is using these same values to simulate cohesive sediment transport per the guidance of the HEC-6T model owner/developer, Tony Thomas (Mobile Boundary Hydraulics [MBH]). These parameters appear to work in combination to provide realistic results whereby sand-sized particles tend to be deposited and not re-suspended from the streambed, while the reverse is true for clay and silt particles (Dr. Evan Canfield, personal communication 2001). Other combinations of parameters tend to reverse this behavior in HEC-6T, which was determined to be unrealistic.

6.3 Streambed Sediment Erosion and Re-suspension

Streambed sediment erosion was purposely not modeled in FY00 for several reasons, the most important being that the Site streams are well armored with cobbles and vegetative cover. Furthermore, HEC-6T was developed to estimate non-cohesive sediment (i.e. sand) transport, whereas the erodible sediments in Site streams are predominantly cohesive clay and silt. Finally, adding channel erosion to the Actinide Transport Models was determined to be unwarranted because the predicted actinide concentrations were high enough to challenge water-quality compliance, and adding the streambed erosion component only increases predicted actinide concentrations. In this FY01 report, the AME incorporated channel erosion processes into the HEC-6T sediment transport models. The models contain erodible streambed parameters based on field observations from a September 2001 survey of the Site channels. Cohesive sediment transport parameters for the HEC-6T model were obtained through consultation with HEC-6T model developer, Tony Thomas, and with Dr. Evan Canfield of the Agricultural Research Service in Tucson, Arizona. Dr. Canfield is working on similar HEC-6T modeling for LANL, and he provided the AME with parameters that gave reliable results for the LANL models.

Data for the stream channel characteristics obtained from the sediment field survey in September 2000 were incorporated into the HEC-6T models. The cohesive sediment transport option in HEC-6T was selected to model the channel erosion process. The HEC-6T Users' Guide contains the following warning pertaining to prediction of cohesive streambed sediment transport:

> WARNING: THIS PROGRAM WAS DESIGNED FOR NON-COHESIVE SEDIMENT TRANSPORT. SOME VERY LIMITED COHESIVE THEORY WAS ADDED FOR SPECIAL PURPOSES AS IT MIGHT RELATE TO NON-COHESIVE TRANSPORT. THIS CODE WAS NEVER INTENDED TO MODEL COHESIVE SEDIMENT TRANSPORT EXCLUSIVELY. HOWEVER IT HAS BEEN USED ON SOMESUCCESSFUL APPLICATIONS INVOLVING COHESIVE SEDIMENTS BY CAREFULLY POSING THE QUESTIONS AND CONFIRMING THE MODEL TO PROTOTYPE DATA.

Because Site data are limited with respect to grain-size distribution of transported sediment, the above warning serves as a caveat to the results contained herein.

The HEC-6T models were run with erodible stream beds except in areas where the channels were observed to be armored with large cobbles, rip rap material, concrete, or other resilient, large-diameter materials. Comparison of the WEPP-estimated sediment yields from the hillslopes with the total yields estimated by HEC-6T give an indirect estimate of the amount of channel erosion (a.k.a. scour or re-suspension) that is predicted to occur. Sediment yield results and estimations

37

of the channel erosion component of the total sediment yields are shown in Tables 3, 4, 5, and 6 and illustrated in Figure 9. As expected, the models that include streambed erosion typically predict higher sediment yields and consequently higher actinide concentrations. However, the results for Woman Creek indicate that the hillslope sediment deposition in the channel is greater than the erosion / re-suspension. The results are realistic in comparison with Site monitoring data, but estimated concentrations are generally higher than have been measured. Therefore, the models likely overestimate sediment and associated actinide transport.

The FY01 results in Tables 3, 4, and 6 show that the predicted total sediment yield is comprised of a higher percentage of bed material at lower flows (e.g. 1- and 2-year events) than at higher flows (e.g. 10- and 100-year events) for the SID, Mower Ditch, and Walnut Creek. This is consistent with the expected behavior of the natural system because more sediment yield is expected to be delivered to the stream channels from hillslope erosion during extreme events, but very little hillslope sediment is observed to be delivered to the stream channels during smaller events. However, the results are different for Woman Creek as shown in Table 5 and Figure 9. The Woman Creek models indicate that there is more sediment deposition occurring than channel erosion. Woman Creek has some substantial deposition areas in Pond C-1 and in the Woman Creek Bypass Canal that routes Woman Creek around Pond C-2.

As stated in the previous section, HEC-6T initially predicted re-suspension of the very-fine to coarse sand and deposition of cohesive sediments. This result is inconsistent with field observations and measurements, which indicate that the erodible material in the stream channels is primarily silt and clay. Consultation with HEC-6T model developer Tony Thomas (MBH) and Dr. Evan Canfield (ARS) provided parameters that reversed this trend. Per their recommendations, the AME updated the HEC-6T models to include a broader range of particle sizes for streambed sediments. Also, the runoff hydrographs in HEC-6T were modified by addition of a brief period of baseflow with no tributary inflows. This baseflow period brings the streambed sediment particle-size gradation into equilibrium with the channel hydraulics prior to the start of the runoff hydrograph. A discussion of the procedure used to calibrate the streambed sediment gradation in the models is presented in Appendix E. The models now predict larger yields and higher concentrations than published in the 2000 Report due to incorporation of the channel erosion processes.

A criticism of the 2000 modeling effort was that model results were compared to stream monitoring data collected by automatic samplers that have an intake port positioned in the stream at a fixed depth (usually near the bottom). The question posed was whether the samplers represent the vertical distribution of particle sizes in the water column from the water surface to the streambed. In response to this concern, the Site Surface Water Group deployed automatic samplers to GS10 and SW093 (Figure 3) to collect stormwater runoff samples at the same time that manual, depth-integrated sediment samples were obtained. One storm was sampled at each location in FY01. The observed total suspended solids concentrations are listed in Table 7. These limited results indicate that there is no difference between the two sampling methods for these small, well-mixed streams. However, a better data set is needed to statistically verify that conclusion.

Comparison of total suspended solids and suspended sediment (TSS) concentrations in historical Site stormwater monitoring data reveals that the TSS measurement underestimates the suspended sediment yield (Figure 10). This is explained by the differences in the analytical techniques, and has been evaluated and explained by Gray et al. (2000). Therefore, calibration of the sediment transport models to TSS data could cause the models to under-predict sediment yields. The AME models overestimate measured yields determined by TSS. This general understanding of the data and the models tends to slightly reduce uncertainty, but the extent of that reduced uncertainty is difficult to quantify.

6.4 Modeling Small Storms to Evaluate HEC-6T Performance

Part of the evaluation of the streambed erosion component of HEC-6T included modeling typical (i.e. less than 1-year return period) precipitation events where little to no overland flow is predicted by WEPP. This was done in an attempt to calibrate the streambed erosion component of HEC-6T by controlling the influence of hillslope sediment yields. In general, HEC-6T channel erosion simulation appears to predict sediment yields to within a factor of two, but

39

WEPP hillslope sediment yields appear to be overestimated by about an order of magnitude. Table 7 shows the results of modeling selected storms for which monitoring data are available.

The available Site data were reviewed to select storms for which measured runoff and TSS concentrations are available. Data are available for GS02 on Mower Ditch for two storms that meet the criteria of this exercise, one storm on February 18-19, 1997 with a yield of 0.4 kilograms (kg) and a second storm on April 3, 1997 with a yield of 7 kg. The runoff hydrographs for these storms were input to HEC-6T, and an erodible streambed model was used to generate estimated sediment yields at GS02 which were compared with the monitoring data.

The small storm models for Mower Ditch predict sediment yields that are about 2 to 72 times higher than the yields computed from the monitoring data (Table 7). These results verify statements in the FY00 report that the modeling technique predicts results to within an order of magnitude, and that the results are conservative in that predicted sediment and associated actinide yields are larger than actual yields.

Data are available for SW027 on the SID for April 30-May 1, 1999 with a yield of 73 kg and for July 31-August 1, 1999 with a yield of 77 kg. The error associated with the low TSS concentrations combined with error in the flow measurements may be a factor of two or more. Therefore, the estimated measured yields could be in error by as much as 50 percent. Therefore, caution is warranted when comparing the model results to the monitoring data for the small storms. Overall modeling the small storms further demonstrated that the WEPP and HEC-6T models are believed to predict sediment yields to within about an order of magnitude.

The monitoring data are the most reliable estimators of sediment- and associated actinide-discharge curves for low flows, and the modeling results are used to extend those sediment- and actinide-discharge curves for large storms. There are no data for large floods at the Site, except for the May 17, 1995 event. As mentioned in the 2000 Report and in several review comments on that report, additional hillslope erosion and sediment yield data are needed for large storms for comparison to model predictions to evaluate model uncertainty.

6.5 Walnut Creek Model Refinements

Estimated sediment concentrations for the No Name Gulch segment of the Walnut Creek sediment transport models were inconsistent with the predicted concentrations for other segments of the models. Evaluation of the models indicated that the geometry of a small stock pond located at approximately 1,000 m upstream from the mouth of No Name Gulch was not represented. Incorporation of the stock pond geometry into the models improved the sediment yield and concentration estimates for No Name Gulch. Figure 11 shows a comparison of the HEC-6T-estimated No Name Gulch sediment concentrations for the new model geometry that includes the stock pond.

After the AME had completed the 2000 sediment transport models, the Site completed installation of the McKay Bypass Ditch Pipeline in the Walnut Creek watershed. The pipeline diverts up to 3.1 m^3/sec (110 cfs) from the McKay Bypass Ditch, located approximately 305 meters (1,000 feet) upstream from the confluence of McKay Ditch with Walnut Creek. The new pipeline has been incorporated into the routing for the sediment transport models for Walnut Creek. In the models, the diversion is located at 285 meters (934 feet) upstream from the confluence of McKay Ditch with Walnut Creek, and it removes 99 percent of all of the modeled flow up to 3.1 m^3/sec (110 cfs) from the McKay Ditch tributary.

6.6 Climate Data Update

A simulated climate data file based on the climate record for Fort Collins, Colorado was used to generate the 2000 Report erosion continuous simulation results. The climate generation model, CLIGEN, was used to create the climate data file. As stated in the 2000 Report, the Fort Collins data were used because the Site has similar annual average precipitation to the Fort Collins station, and the Fort Collins station has a 92-year period of record. Actual Site climate data for calendar years 1995 – 1998 were imbedded into the simulated climate file as years 15 through 18. In FY01, Site data for 1999 were added to the climate file as year 19.

41

6.7 FY01 Erosion Plot Data—Particle Size and Actinide Enrichment

An enrichment factor is a ratio of the quantities of a material in a soil source term and in the sediment derived from the source term. The term "enrichment" may be applied to the ratio of the particle-size distributions of the sediment and parent soil or it may be applied to the ratio of the quantity of actinide in the source term as compared to the sediment. Limited data are available for determination of actinide enrichment for sediment particles derived from upland erosion. The AME models use enrichment factors derived from data obtained from Ranville et al. (1999) for Site soils. Ranville separated the soils by particle size and determined the actinide content of each fraction. The AME used these data to compute enrichment factors for Pu and Am in the soils. However, in FY00, there was some question about whether the enrichment factors are different for parent soil and eroded sediment due to potential preferential transport and/or dis-aggregation of particles along the hillslope between the erosion source and the stream.

In FY01, the AME installed two erosion plots on a hillslope in the GS42 drainage (Figure 12) to collect eroded material for determination of particle size enrichment and actinide enrichment. Runoff and erosion rates were also measured. Each of the two plots have dimensions of 3m wide by 10m long on an approximate 9 percent slope. One plot was left in a natural state, and the other was clipped close to the ground surface with removal of the clippings by hand to simulate a disturbed, or possibly a burned, area. The plots were designed to be similar to rain simulation study plots installed at the Hope Ranch by the Colorado State University (CSU)/LANL study in 2002 (Figure 13). The runoff from each of the plots is collected in a gutter that drains to a plastic container. After a storm event, the containers are removed, and the contents are containerized for analysis. Gaging station GS42 was also upgraded by installing a collection trough in the drainage swale upstream from the flow meter and flume. This upgrade put the automatic sampler intake in a better position to collect more representative samples.

Data were collected for four storms: three in May 2001, and one in July 2001. The data obtained for runoff and erosion rates are shown in Table 9. The May 7, 2001 storm had a measured depth of 20.6 mm (Safe Sites of Colorado, 2001, Surface Water Monitoring Data, electronic communication). Smaller storms on May 20 and May 29 had measured precipitation of 8.3 and

42

6.3 mm, respectively. The July storm was much more intense than the May storms, but only had a depth of 4.9 mm.

The erosion plot measurements indicate erosion rates of about 10^{-5} to 10^{-2} metric tons per hectare (T/Ha) with runoff coefficients of about 0.01 to 0.18 (i.e. 1 to 18 percent of applied rain runs off). These measurements compare well with the 2000 Report results of 0 to 0.027 T/Ha for the 1-year, 11.5 hour, 35 mm rainstorm with a runoff coefficient of about 0.05. It is not possible to evaluate the 2000 Report conclusion that the models are overestimating erosion by about an order of magnitude, but these data give confidence that the model results are representative of observed erosion rates.

Dr. James Ranville analyzed the first erosion plot samples, collected on May 7, 2001, at Colorado School of Mines along with a sample from GS42 for the same storm. The particle size distributions of the samples are shown in Figure 13. The data indicate a shift in the particle size distribution from the erosion plots to the bottom of the hillslope. The erosion plot samples have a higher proportion of larger particles than the GS42 sample at the outlet of the drainage about 400 meters downhill. This is an expected result because the watershed length presents a farther distance for particle to travel and more opportunity to settle out. This would lead to smaller particles delivered to the outlet of the watershed at the GS42 flume. But, in a large storm, the rills and channels in the watershed may be more efficient sediment transport pathways, which could deliver larger particles to the watershed outlet.

The actinide data were not available in FY01, so computation of actinide enrichment was not possible. Another sample collected in early July produced a substantial amount of runoff on the plots, and the samples that resulted were sent to Dr. Ranville for particle-size analysis and actinide enrichment measurements. The small number of data obtained from these observations will be used to understand the uncertainty in the actinide transport models, but they will not be used to update the actinide transport simulation results contained herein.

6.8 Actinide Content of 903 Pad Area Improved Gravel Roads

The actinide transport models use computer-generated grids of Pu and Am activity in the Site surface soils to calculate the quantities of actinides delivered to the streams. The grids were developed using Kriging, a geostatistical method which interpolates spatially distributed measurements and estimates activities in areas that lack measurements. The Kriged data are mapped showing areas of varying Pu and Am content in the surface soil. These maps are called isoplots. Appendix B of the 2000 Report, included on the CD-ROM in Appendix A of this 2002 report, discusses the Kriging technique and the results obtained for the AME isoplots. However, the Kriging for the 2000 isoplots did not include data for the improved gravel roads surrounding the contaminated 903 Pad and Lip area. Therefore, the roads were estimated to have activities similar to the surface soil in the range of 100 to 1429 pCi/gram. There were few analyses of the improved gravel roads to confirm that the actinide content was as high as the surrounding soils. The AME collected samples of those roads in FY01. The data are shown in Figure 15. The data indicate that the average activity of the roads is about 4 picocuries per gram (pCi/gram). Therefore, the 2000 models were conservative due to overestimation of the road actinide activities by a factor of 20 to 300.

In FY01, the Pu and Am Kriged grids were edited by changing the activities for the grid cells touching or overlaying a road. The original Pu and Am isoplot maps are based on grids with 6.97 m^2 (75 ft^2) grid spacing. The original grids were converted to a 1.2 m^2 (12.5 ft^2) grid spacing, and then the grid cells touching roads were edited in GIS to the average activities measured in the road soils. This procedure was done only for the roads surrounding the 903 Pad and Lip area and resulted in lower predicted actinide activities in the SID surface water (Section 7). The grids were edited a second time to model road re-vegetation scenarios. Two of the road re-vegetation scenarios simulate addition of topsoil to the roads, which would cover any residual contamination in the original road surface. Therefore, all of the road grid cells were edited to a background activity of 0.5 pCi/g Pu and 0.2 pCi/g Am for the road re-vegetation scenarios that call for added topsoil. A comparison of the original and edited grids is in Figure 16.

The grids updated for the road samples have changed the actinide mobility maps for the design storms in the SID watershed. The actinide mobility maps were developed by the AME to illustrate areas where actinides have the greatest potential to move by overland flow and erosion processes. The actinide mobility maps are created by multiplying the erosion map grid by the actinide activity isoplot grid to obtain a representation of actinides in soil that moves by erosion. The actinide mobility maps are used in Section 7 to compare the hydrologic scenarios.

7.0 RESULTS

Modeling results for scenarios related to erosion and sediment transport are described in the following sections. Erosion scenarios include road re-vegetation, range fires and IA reclamation, while sediment transport scenarios include channel erosion and pond and stream reconfiguration.

7.1 Erosion Scenarios

Two general erosion scenarios were modeled in FY01: 1) road re-vegetation; and 2) range fires. Road re-vegetation was evaluated because the 2000 Report demonstrated that the improved gravel roads and unimproved roads in the Site Buffer Zone contribute substantial sediment yield to the streams. At regulatory closure, some of these roads could be re-vegetated or will naturally regain their rangeland cover of upland grasses and forbs. The impact of road re-vegetation on actinide transport was evaluated to weigh the benefits to water quality. Range fires were evaluated in response to stakeholder concerns about the impacts of fire on actinide transport and to assess range management practices such as controlled burning for fire load reduction. In addition, this report presents preliminary results of IA re-vegetation on actinide transport. Parsons Engineering Science performed the IA configuration modeling with support from the AME, as part of the Kaiser-Hill Land Configuration Design Basis Study.

7.1.1 Road Re-vegetation

Three separate road re-vegetation scenarios were modeled to evaluate different re-vegetation techniques. The first technique allows a strip of mesic mixed grassland cover to naturally grow down the middle of the existing improved roads to form dual-track mountain bike paths. This is likened to a "No Action" scenario. The second technique establishes reclaimed grassland species on the existing improved road soils. This scenario is likened to hydro-mulching reclamation-type species of grass and forbs directly on the existing roads. The last technique establishes reclaimed grassland species on roads amended with topsoil. Two thirds of the road surface is re-vegetated for the bike path scenario. The other two practices provide complete re-vegetation of the road surface. Appendix A contains the WEPP input data for the road re-vegetation scenarios.

The WEPP soil input data files were modified for the road re-vegetation scenarios. WEPP soil input data files for hillslopes that are roads or for hillslopes containing OFEs that are roads were edited. For the bike path scenario and the reclaimed grassland scenario without added topsoil, the hydraulic conductivity of the surface soil layer was increased to a level that is consistent with surrounding natural soils. For the scenario that includes amending the roads with topsoil, the soil data for improved roads (sandy loam) were replaced with soil data for natural hillslopes (Denver-Kutch Midway Clay Loam, a.k.a. Side Slope Soil). The soil hydraulic conductivity values were increased for the topsoil-amended roads such that topsoil-amended roads have runoff coefficients similar to uphill OFEs or adjacent hillslopes.

Tables 10 through 13 show how road re-vegetation will affect sediment yields. Table 10 compares the results of modeling the 100-year, 6-hour precipitation (97.1 mm) event for the three road re-vegetation scenarios. After several model runs and a substantial amount of modeling data review, the AME Modeling Team concluded that the results for the 100-year event modeling do not present a consistent trend for reasons that remain unexplained. Possible reasons for the lack of a consistent trend include: 1) complex basin hydrologic response for the extreme 100-year runoff event; 2) differences in the timing of peak flows scouring the streambed, thus hiding the effect of the road re-vegetation, and 3) artifacts in the conversion of the WEPP output to HEC-6T using the triangular unit hydrograph algorithms.

Based on comparison of the actinide yields for the three re-vegetation scenarios in Table 10 (i.e. ignoring the comparison to existing conditions), the highest predicted actinide yields are for the bike path (i.e. No Action) scenario. Therefore, the model confirms the intuition that reclaiming the roads will likely reduce actinide mobility. However, comparison of the predicted actinide concentrations in Table 10 indicates that road re-vegetation might not have an effect on actinide concentrations in the stream because all of the predicted concentrations are essentially the same within each watershed. Currently, the roads have very high erosion rates due to their low hydraulic conductivity and fine-sand texture, but the roads comprise a small fraction of the total drainage area in each watershed; making them a relatively small sources of actinide-containing sediment. Figures 17, 18, and 19 show the predicted actinide concentrations in Site streams for the road re-vegetation scenarios for the 100-year event, which indicate subtle differences in surface-water actinide concentrations for the road re-vegetation scenarios.

The WEPP model was run in the continuous-simulation mode for a 100-year period for the road re-vegetation scenarios. Tables 11 through 13 show the results of the 100-year annual average erosion rates for the re-vegetated hillslopes in each watershed. The model results indicate that road re-vegetation will decrease annual average erosion of the hillslopes containing roads by over 70 percent and reductions in erosion rates of over 90 percent might be possible.

No test plot data or other studies have been done at the Site to provide data for calibration of the road-revegetation scenarios. The erosion rates for the existing roads were compared to studies done by Elliot et al. (1994 and 1995) in the 2000 report, but no data for re-vegetated roads were obtained for comparison herein.

7.1.2 Range Fires

Range fires that could be started by lightening (which occurred in 2000 and 2001), sparks from railroad cars (as in 1999), or other accidental events would reduce vegetation cover and increase erosion, especially if a large precipitation event was to occur immediately after the rangeland is burned. Concern was raised by stakeholders that range fires in contaminated areas could increase actinide transport in streams.

Four range fire scenarios were evaluated in the SID watershed where the most contaminated surface soils are located. Figure 20 illustrates the aerial extent of each range fire scenario. In the first scenario (Scenario A), a fire burns the 903 Pad Area up-gradient from the IA inner perimeter road. This area is SID Hillslope 15 in the AME WEPP models. The second scenario (Scenario

B) extends the range fire from the 903 Pad Area east to the upper portions of Hillslope 18. (Note that the upper portion of Hillslope 17 remains as an improved gravel road with no re-vegetation for the second scenario.) The third scenario (Scenario C) extends the fire from the 903 Pad southeast (downhill) to the lower half of Hillslope 18. The fourth scenario (Scenario D) burns most of the aerial extent of contaminated soil (from the 903 Pad to the eastern end of the SID watershed, plus about seven hectares in the Woman Creek watershed). Each fire stops at the SID road up-gradient from the SID.

The calibrated WEPP input files obtained from the FY00 AME modeling project were modified to simulate burned rangeland vegetation and soil. Runoff and sediment yield data for rain simulator plot studies were used to calibrate WEPP to simulate range fire conditions. Rain simulator data for burned test plots were obtained from the CSU study conducted by Mat Johansen (LANL), Dr. Tom Hakonson (CSU), and their colleagues at the Hope Ranch (adjacent to the Site) in 1999. Photographs of the burned rain simulator test plots are shown in Figure 14. The photographs and the data in Appendix C show that the test plots were burned to eliminate all of the vegetative cover. Photographs and measurements of a controlled burn at the Site in 2000 show that only a small fraction of the cover is removed by a fire, and the remaining cover provides some protection from raindrop impact and erosion (Figure 21 and Appendix C). Burn conditions may vary depending on many factors, but for the 2000 controlled burn, the cover was not reduced nearly as much as in the CSU study. Therefore, a balance between the CSU/LANL study data and the cover characteristics observed in the controlled burn was used in the burn scenario calibration. A description of the calibration procedure is contained in Appendix C.

The WEPP model was run in single-storm mode for a 100-year, 6-hour storm for the range fire scenarios. This storm predicts erosion from the entire SID watershed and represents a worst-case scenario. Figure 20 shows how erosion is affected by each range fire scenario, with erosion increasing in each of the burned areas. Figure 22 shows how predicted actinide concentrations and yields are affected by each of the range fire scenarios. The actinide yield to the end of the SID (Gaging Station SW027) generally increases with increasing burned area as expected, but the actinide yield also depends on where the fire is located. The fires on more contaminated soils yield more actinides to the stream. For example, when the lower portion of hillslope 18 is burned, but not the upper portion, a lower actinide yield and concentration are predicted than when the upper portion of the hillslope burns. Generally, the models predict that range fires increase actinide yield to SW027 by about 45 to 114 percent, and actinide concentrations are predicted to increase by about double for a 100-year, 6-hour event. Runoff, erosion, and actinide mobility increase downstream from the burned areas. However, dilution effects from the increased runoff in the burn area actually reduced the overall actinide concentration values.

For the range fire scenarios, a large, 100-year precipitation event occurs immediately after the range fires occur. The timing of the precipitation event and the quality of cover that exists at the time of the burn are very important variables in determining how much actinide mobility is increased by range fire (Johansen et al. in Press). Figures 23 and 20 show the time series of vegetation recovery in the controlled burn area and an area near the East Gate burned from a lightning strike in 2000, respectively. The vegetation recovered quickly in these areas, and the recovery is completed in a matter of a few months.

Observations by the Site Ecology Group indicate that areas taken over by noxious weeds recover more slowly from fire than the rangeland grasses. A lightening strike fire in the Rock Creek drainage in July 2001 was monitored regularly by the Site ecologists. Areas inundated by weeds slowly recovered with more weeds over a period of months, but the areas with natural grassland vegetation recovered with grasses in a matter of two weeks (Jody Nelson, Site Ecology, personal communication and photographic data 2001). This is an example of how range management relates to fire and actinide transport. Healthy, natural cover free from noxious weeds could help reduce erosion potential and thereby control actinide transport, especially after a range fire.

7.1.3 Industrial Area Reclamation

The LCDB project is determining the factors and values that will affect final Site configuration for long-term stability at regulatory closure. Part of that project is the evaluation of how the land configuration will affect water quality with respect to actinide concentrations. The AME supplied the WEPP modeling tools and calibrated input data necessary for the LCDB contractor,

49

Parsons Engineering Science, to conduct WEPP modeling of a re-vegetated IA. AME reviewed the IA hillslope delineations, output data, and final erosion maps for the LCDB project. The reclaimed IA erosion map is published herein (Figure 24). The IA reclamation depicted by LCDB "Scenario 0," depicts the IA after active remediation and re-vegetation, but it does not constitute a final design for the IA configuration at regulatory closure. The map is a tool for beginning to evaluate alternatives for final land configuration.

The IA was modeled such that Flatirons Series and Nederland Series soils (sandy clay loams) with xeric tall grass prairie vegetation cover the majority of the IA pediment. The flanks of the pediment are assumed to have Denver-Kutch Midway Series soils (clay loams) covered by xeric tall grass prairie.

The IA reclamation scenario assumes that active remediation is completed. Areas that are currently or historically covered by impervious surfaces (i.e. concrete, asphalt, etc.) are assumed to be re-graded with the sandy clay loam soil and contain Pu activity at 0.5 pCi/g and Am activity at 0.2 pCi/g. The 903 Pad and Lip area is assumed to be remediated by removal of Tier I and co-located Tier II contamination and by placement of fill at background Pu and Am levels. An evapotranspiration cover composed of clean fill is assumed to be in place over the Solar Evaporation Ponds area.

Sediment transport and actinide transport models were created for the IA reclamation scenario to predict actinide concentrations in surface water at regulatory closure (Figure 24). The predicted IA reclamation model actinide concentrations (2.915 pCi/L Pu-239,240 and 0.853 pCi/L Am-241) for the 100-year, 6-hour (97.1 mm) event are a factor of five higher than for existing conditions (0.629 pCi/L Pu-239,240 and 0.253 pCi/L Am-241). The model assumes that no road-side ditches, culverts or other drainage features will hinder runoff from going directly to the streams. Also, after IA reclamation, most of the water that runs off from impervious industrialized surfaces will infiltrate into the soil and not be available to dilute contaminated sediment delivered to the stream channels. These factors will be considered in conjunction with the results of the Site-wide Water Balance Study to design a suitable regulatory closure configuration that is protective of surface-water quality. In general, re-vegetation of the IA might result in higher actinide concentrations due to decreased dilution, but actinide yields will decrease (KH, 2002).

7.1.4 Updated SID Erosion and Actinide Mobility Results

The erosion and actinide mobility maps for the SID were updated significantly in FY01. The road materials were sampled and analyzed for actinide content in order to edit the actinide isoplot grids. The edited actinide grids used to compute actinide yields to the streams for the FY01 modeling are contained in Appendix D. An error in the WEPP model input for vegetation cover on SID Hillslope 16 was also discovered and corrected. The WEPP output for Hillslope 16 is now consistent with the output for the rest of the SID watershed. Lower erosion and sediment yields are now predicted for Hillslope 16 than in the 2000 Report. Updated erosion maps for the SID are shown in Appendix D. Updated results for the SID erosion and actinide mobility modeling are presented in the erratum contained in Appendix B. The changes to the SID watershed modeling are incorporated into the updated results for the design storm models shown in Figures 25 to 30.

Figure 25 shows that the predicted Pu concentration at SW027 for the 1-year, 11.5-hour, 35-mm storm is now below the Site action level, which is consistent with most monitoring data for SW027. Figure 29 shows that the predicted Pu concentration at SW027 for the May 17, 1995 flood is about 7.5 picocuries per liter (pCi/L), compared to the monitoring data at about 2.0 pCi/L sampled on the rising portion of the hydrograph. These comparisons provide enhanced confidence in the model performance.

7.2 Sediment Transport Scenarios

7.2.1 Channel Erosion and Streambed Re-suspension

The 2000 Report sediment transport modeling was done assuming that the streambeds were armored and contributed no sediment load to the streams. This was a known over-simplification of the system that was implemented to focus solely on the transport of hillslope-derived actinides and avoid the complications of channel erosion and re-suspension of actinide-containing

51

sediments. Moreover, the AME did not have adequate data to begin to parameterize a reliable channel erosion component of the model. In response to stakeholder concerns and various peer reviewers of the 2000 work, the AME collected field data and incorporated channel erosion/streambed sediment re-suspension into the HEC-6T models. The AME FY01 data collection effort for the channel erosion modeling is discussed in Sections 6.2 and 6.3.

The six design storms were used in the improved HEC-6T sediment transport models to predict sediment transport for models with channel erosion set according to observations in the September 2000 streambed sediment survey. The HEC-6T modeling predicts that scour of the channel supplies a greater proportion of the sediment yield for smaller precipitation events than for larger ones. This is expected because overland flow at the Site occurs only for large, intense precipitation events or during extreme wet periods.

Hillslope actinide activities were used for re-suspended channel sediments in the models. Inspection of the soil and sediment activity data shows that the measured hillslope soil activities are higher than the measured streambed sediment activities. As explained in Sections 6.2 and 6.3, the hillslope actinide activities were used in the models instead of the streambed sediment activities. Therefore, the predicted actinide concentrations tends to be overestimated to a greater degree with smaller storms than with larger storms because a larger percentage of the actinide transport is attributed to channel erosion for smaller storms.

Overall, the predicted actinide concentrations in the SID, Woman Creek, Mower Ditch, and Walnut Creek increased with incorporation of channel erosion. Results for each design storm in each watershed, updated to include channel erosion processes, are illustrated in Figures 25 to 33. Actinide transport modeling results for the SID are discussed in Section 7.1.4 and illustrated in Figures 25 to 30. Predicted actinide concentrations in the Mower Ditch are realistic for the 1-year, 11.5-hour, 35-mm event, but the results for the other events are about one order of magnitude higher than any monitoring data values for gaging station GS02, Mower Ditch at Indiana Street (Figure 31). However, these types of extreme events have not been sampled at GS02, except for the May 17, 1995 event. Modeling results for Woman Creek are shown in Figure 32. Walnut Creek results show that higher concentrations are predicted at gaging station

52

GS03, Walnut Creek at Indiana Street for smaller events than for larger events. This could prove to be true due to dilution effects at higher flows. Reportable values for Pu and Am at GS03 have only occurred during low-flow periods, not for high flows.

7.2.2 Pond and Stream Configuration Alternatives

Pond and stream configuration alternatives were modeled to help incorporate actinide migration considerations into the design of drainage systems for regulatory closure. These scenarios are not intended to advocate any particular alternative for configuration of the Site watersheds. Exercise of the appropriate standard of care for design of the final Site configuration necessitates consideration of many variables in addition to actinide migration, such as wetlands, endangered species, water resources, water rights, mineral rights, geotechnical stability, and many other factors. Removal or modifications of detention ponds are issues that will receive considerable attention in the course of achieving regulatory closure.

7.2.2.1 Model-Estimated Sediment Deposition in Detention Ponds

The Site detention facilities are known to provide protection of downstream water quality. The ponds remove a substantial portion of the actinide load from the water column (RMRS April 1998, 2000a, 2001b). Santschi et al. (2000 and 2001) have found that average particle residence times in the ponds are on the order of a few days. In other words, most of the particles that are large enough to settle out in the ponds do so in less than a few days. These measurements were made for ponds operated in a detention mode, whereby the ponds are filled with no outflow and then discharged in batch.

In the HEC-6T models, the ponds are full with the flow routed over the emergency spillways of each dam in order to streamline model computation and to make the models conservative estimators of sediment transport. An analysis of the model-estimated sediment trap efficiency for Ponds A-4, B-5, and C-1 is presented in Table 14 to demonstrate the ability of HEC-6T to simulate sediment removal processes in ponds. Table 14 compares the model-estimated trap efficiencies for Ponds A-4, B-5, and C-1 to theoretical trap efficiencies estimated by USBR methods (Strand and Pemberton 1982). The results show that the HEC-6T estimated trap efficiencies are lower than the theoretical trap efficiencies when the trap efficiency is calculated for all particle sizes including clay and silt (i.e. Total Sediment Trapped) . However, HEC-6T is predicting that all of the sand-sized particles are trapped Ponds A-4 and B-5, and nearly all sand-sized particles are predicted to be trapped in Pond C-1. The model-estimated trap efficiencies are low because the ponds are assumed to be full in the models, which means that the residence time for water flowing through the ponds is short compared to the residence times inherent in the USBR method. Overall, the models simulate realistic sediment removal, but is conservative (i.e. over-estimates) relative to clay and silt transport through the ponds.

7.2.2.2 Woman Creek Hydrologic Modifications

Replacement of Pond C-1 in the Woman Creek watershed with an armored (non-erodible), engineered channel was modeled in HEC-6T with the same runoff hydrographs, hillslope sediment yields, and channel erosion characteristics as the model for existing conditions. The model results for this scenario are summarized in Table 15 and Figures 34 and 35.

Pond C-1 is providing a benefit to water quality in Woman Creek. The model results indicate that Pu and Am concentrations would increase by about 43 percent for the 1-year, 11.5-hour, 35-mm event and by about 25 percent for the 100-year, 6-hour, 97.1-mm event if Pond C-1 is removed. Model-estimated sediment yields increased by about 35 percent for the 1-year event and about 30 percent for the 100-year event for the Pond C-1 removal scenario. Pu yields increased by 48 percent for the one-year event and by 20 percent for the 100-year event, and Am yields increased by 74 percent for the 1-year event but stay essentially unchanged for the 100-year event for the Pond C-1 removal scenario.

Removal of Pond C-1 will cause increased sediment and actinide yields and concentrations in Woman Creek. However, the models indicate that the average Pu concentration would be about 0.05 for a one-year event, which is below the 0.15 pCi/L Rocky Flats Cleanup Agreement (RFCA) Action Level. Note that the RFCA Action Level is for a 30-day moving average, not a single event as modeled herein.

A second scenario was run for Woman Creek whereby the western one-third of the SID channel was routed into Woman Creek via a hypothetical, armored, engineered channel in a historic drainage swale south of Building 881. The channel was modeled to flow to Woman Creek upstream of Pond C-1. This scenario keeps Pond C-1 in place. The scenario was derived because most of the flow tributary to the SID comes from the IA and is discharged to the SID via the 460 Culvert (a.k.a. gaging station GS22) and other culverts from the south sides of Buildings 664, 850, and 881. Monitoring data for these inflows shows that the water is of good quality and low actinide content. The IA discharge water provides the driving force for transport in the SID, and it is detained in Pond C-2 where it is managed for batch releases to Woman Creek. Therefore, "SID routed to Woman Creek" scenario was tested to determine if such a configuration would be beneficial to SID water quality without impact to Woman Creek.

The results of the "SID routed to Woman Creek" scenario model (Table 16 and Figures 34 and 35) indicate that the IA discharge re-suspends enough activity from the SID channel to impact Woman Creek water quality. Most of the activity is derived from channel scour. Predicted Pu concentrations at GS01 increased by 67 percent for the 100-year, 6-hour, 97.1-mm event and by a factor of 22 for the 1-year, 11.5-hour, 3-mm event for this scenario. Sediment yields increased by 42 percent for the 1-year event and by 21 percent for the 100-year event. Pu yields increased by over 2 orders of magnitude, and Am yields increased by up to 65 times for the 1-year event. Pu and Am yields increased by 84 percent and 1 percent, respectively, for the 100-year event. Larger increases in sediment and actinide yields for the smaller, 1-year event are consistent with the fact that channel erosion generally constitutes a larger portion of the total yield for smaller events.

7.2.2.3 SID Hydrologic Modifications

The "SID routed to Woman Creek" scenario model has a counterpart model called the "Truncated SID" scenario model, which is the eastern two-thirds of the SID channel that would still be routed to Pond C-2 (Figure 36). This model results in a 49 to 92 percent decrease in sediment yield to Pond C-2 for the 100-year and 1-year events, respectively. Actinide load to Pond C-2 generally decreases by less than 10 percent for the 100-year event and by over as much as 48 percent (e.g. Am) for the 1-year event. The yields to Pond C-2 decrease for this scenario because the driving force of the IA runoff is eliminated from the model. However, the predicted Pu concentration at SW027 increased by 61 percent for the 100-year event and increased by a factor of eight for the 1-year event due to decreased dilution from the IA discharge. The model results for the "Truncated SID" and the "SID routed to Woman Creek" scenarios indicate that this alternative would substantially limit sediment and actinide transport to Pond C-2, but actinide concentrations would increase in both the SID and Woman Creek due to decreased dilution by IA flows in the SID and increased channel scour in Woman Creek (Table 16).

7.2.2.4 Walnut Creek Hydrologic Modifications

Replacement of the ponds with hypothetical, armored (non-erodible), engineered channels was modeled in stages through three sequential scenarios in the Walnut Creek drainage. First, the non-terminal ponds (Ponds A-1, A-2, A-3, B-1, B-2, B-3, and B-4) were replaced with engineered channels. Next, the model was modified to remove Pond A-4, leaving only Pond B-5 in place. Finally, Pond B-5 was also replaced with an engineered channel.

The HEC-6T model results for Walnut Creek hydrologic modifications (Figures 37 and 38) are affected by assumptions about channel erosion. Each time a pond or series of ponds is removed from the model, the erodible channels between the ponds and the emergency spillways are replaced with non-erodible stream channels. Removal of the ponds and their sediment-removal capacity is offset by removal of sediment yield from erodible streambeds. This effect is observed in the results in Table 15.

Table 15 shows that sediment yield decreases by 49 percent and actinide yields decrease by about 43 percent when all of the ponds are removed from the 1-year event model. The 100-year event results are different; indicating a 19 percent increase in sediment yield and about a 12 percent increase in actinide yield when all of the ponds are removed from the model. The results for the 100-year event are more realistic because sediment and actinide yields would be expected to increase after removal of the ponds. These results indicate that pond removal in Walnut Creek might not affect actinide concentrations for typical, 1-year return frequency storms, but increases in actinide yields and concentrations are likely for larger storms.

Table 15 also reveals that removal of the interior ponds (i.e. leaving only Ponds A-4 and B-5) has little effect on Walnut Creek actinide yields and concentrations at Indiana Street (GS03). Predicted actinide yields and concentrations are virtually the same as existing conditions for both the 1-year and 100-year events for this scenario. This is consistent with existing conditions because Ponds A-4 and B-5 almost always discharge water of a quality below RFCA Action Levels with respect to actinides, despite the fact that no water is routed through the non-terminal ponds. In general, the results indicate that removal of the detention ponds from Walnut Creek will increase sediment yields and actinide concentrations, but actinide concentrations are predicted to remain within the same order of magnitude as existing conditions.

8.0 SUMMARY AND CONCLUSIONS

The AME erosion and sediment transport modeling tools were improved in FY01. The AME collected and incorporated new data into the models to improve their prediction capabilities and reduce the model uncertainty. The actual reduction in uncertainty cannot be quantified, and predicted actinide concentrations continue be estimated to within about an order of magnitude of the measured results (Appendix D).

Hydrologic scenarios were modeled to predict sediment yields and both actinide concentrations and yields in surface water. The modeling results provide insight into alternative conditions and management practices for regulatory closure of the Site. The results in this report are intended to provide information for design engineering and long-term Site management and stewardship. The scenarios that were evaluated to determine the effects on actinide migration via erosion and surface-water transport processes are:

- Road re-vegetation
- Range fires
- Industrial area reclamation
- Channel erosion
- Hydrologic modifications to streams and ponds

The AME modeling process was used to evaluate these effects, and the results provide the following insight with respect to surface-water quality protection under the RFCA Action Level Framework for actinides.

- The models predict that re-vegetation of Site roads will benefit receiving-water quality. Road re-vegetation was not shown to affect surface-water concentrations for the 100-year, 6-hour (97.1 mm) precipitation event. But, the WEPP erosion modeling results indicate that long-term actinide mobility will decrease if the roads are re-vegetated. Addition of topsoil provides a substrate for vegetation, and the topsoil also shields underlying contaminated soil from erosion and overland transport, thus further retarding actinide migration.

- The models predict that range fires in areas with contaminated soils can increase runoff and erosion, thus impacting receiving stream-water quality. The models predict up to about a factor of two increase in Pu concentrations from a fire burning the 903 Pad area and the upper portion of the Lip Area to the east of the 903 Pad. It was also found that both the location and the aerial extent of a fire have an influence on actinide concentrations in surface water in the SID watershed. Actinide concentrations will not necessarily increase with increased burned drainage area. But, actinide yields do increase with increased burned drainage area. These conclusions apply to the SID watershed, but less-contaminated or uncontaminated waterhseds might behave differently.

- The models predict that after active remediation of the Site and reclamation of the IA is completed, residual actinides in the soil will impact surface water. The models predict slightly increased actinide concentrations at Walnut Creek at Indiana Street (gaging station GS03) for reclaimed IA scenarios (example herein: LCDB Scenario 1). Overland transport of actinides from contaminated areas to streams may not be adequately diluted to be protective of surface-water quality in the absence of IA runoff from impervious surfaces. It is important to note that this statement applies to a single storm event, not a 30-day moving average concentration, which is applicable under RFCA. Estimation of 30-day moving average concentrations via the modeling process was not done.

- The models predict that channel erosion generally contributes more sediment and associated actinide load to the stream than hillslope erosion at low flow, and the converse is true for high-flow events. Therefore, it is logical that cleanup of contaminated soils will not completely prevent the possibility of water-quality action level challenges because channel erosion will continue to re-suspend actinides into the water column until the actinides are eventually flushed from the channels. The channel erosion is particularly problematic at low flow when water is not present to dilute the re-suspended actinides.

59

- The models predict that Pond C-1 in Woman Creek benefits water quality with respect to sediment yields and actinide yields and concentrations. Removal of Pond C-1 caused the models to predict increased actinide concentrations for the 100-year event and a slight increase for the 1-year event was observed. However, the predicted average actinide concentration for the 1-year event was less than the RFCA Action Level of 0.15 pCi/L.

- The models predict that sediment and actinide yields and concentrations would increase at Woman Creek at Indiana Street (GS01) if the western one-third of the SID were to drain into Woman Creek. Sediment yields at GS01 would increase by about 40 percent for the 100-year and 1-year events. Actinide yields would increase by as much as 74 percent at GS01.

- As a result of truncating the SID and routing the western one-third of the SID into Woman Creek, actinide yields in the remaining eastern two-thirds of the SID would be reduced. However, actinide concentrations could increase by as much as a factor of eight because dilution water from IA runoff sources would be removed from the SID.

- Removal of Site detention ponds and reconfiguration of Walnut Creek was evaluated to provide insight to hydrologic configuration options at regulatory closure. The models generally indicate that removal of all detention ponds from the Walnut Creek watershed would increase actinide yields and concentrations at gaging station GS03 for the 100-year event. The non-terminal ponds (A-1, A-2, A-3, B-1, B-2, B-3, and B-4) provide a minor water-quality benefit with respect to sediment and associated actinide yields as compared to the terminal ponds. The model results indicate that replacement of the ponds with non-erodible, engineered channels which gradually attenuate the hydraulic gradient of the stream might result in no increase in present actinide yields and concentrations and could actually reduce actinide yields. However, re-establishment of the stream channels through the existing detention ponds is a complex engineering task, and it is not possible to include specific design criteria into the models at this time.

The AME modeling techniques are being used to assist with the Kaiser-Hill LCDB project to evaluate potential future configurations of the Site. The models may also be used for smaller drainage areas for individual cleanup and reclamation projects. The technology has also been presented in many technical forums within the DOE National Laboratories and at technical conferences. The modeling techniques may be applied to soil contamination problems where the constituent(s) of interest are insoluble and strongly associated with the solid phase.

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63

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TABLES

Table 1. Definitions of Frequently Used Erosion Terms[1]

Term	Definition
Deposition	Settling of entrained soil particles.
Detachment	Freeing of soil particles from the bulk soil by raindrop impact and flowing water shear stress.
Interrill	Areas between rills characterized by diffuse, sheet flow.
Interrill erosion	Detachment (see above) of soil particles and transport by sheet flow.
Overland flow	Movement of runoff across the soil surface;, includes sheet flow and rill flow.
Rill	Area supporting concentrated flow; a micro-channel.
Rill erosion	Detachment and transport of soil particles by rill flow (see below).
Rill flow	Concentrated or channelized (in rills) flow of runoff.
Runoff	Precipitation in excess of a soil's infiltration and surface storage capacity; moving across the soil surface.
Sediment discharge	Movement of a sediment mass past a point, dependent on the velocity of flowing water.
Sediment transport	Entrainment and movement of soil particles with flowing water.
Sediment yield	Net result of detachment, transport, and deposition, resulting in sediment moving past a point of interest expressed per unit area and time period.
Sheet flow	Non-channelized flow of runoff across interrill areas.
Soil loss	Amount of soil per unit area and time leaving an area without significant deposition.

[1]Adapted from Weltz et al. 1998.

74

Table 2. Comparison of FY01 Serrated Drop Structure HEC-6T Model Yields With FY00 HEC-6T Model Yields for SID

Event Depth, Return Period, and Duration	FY-00 Original Drop Structure Model Sediment Yield (kg)	FY-00 No Drop Structure Model Sediment Yield (kg)	FY-01 Serrated Drop Structure Model Sediment Yield (kg)
35mm, 1-year, 11.5-hr	11	6	6,152
31.55mm, 2-year, 2-hr	2,298	608	20,567
40.8mm, 2-year, 6-hr	5,675	1,429	24,294
62.3mm, 10-year, 6-hr	15,129	6,673	48,325
74.9mm, May 17, 1995	11,096	2,645	33,851
97.1mm, 100-year, 6-hr	47,938	22,536	84,474

Note: FY01 Serrated Drop Structure Model includes channel erosion, but FY00 models do not.

75

Table 3. Comparison of WEPP-Estimated Cumulative Sediment Yields and HEC-6T Estimated Sediment Yields for the SID at Station SW027

Watershed: South Interceptor Ditch (SW027) *Drainage Area (Ha):* 75.3

Event Depth (mm)	WEPP-Estimated Cumulative Sediment Yield (kg)	HEC-6T Estimated Net Sediment Yield to SW027 (kg)	Portion of Net Yield Attributed to Channel Erosion (%)	Portion of Yield Attributed to Hillslope Erosion (%)
100-Year, 6-Hour, 97.1 mm	31,271	84,474	63%	37%
10-Year, 6-Hour, 62.3 mm	18,899	48,325	61%	39%
5/17/1995, 74.9 mm	11,091	33,851	67%	33%
2-Year, 6-Hour, 40.8 mm	4,663	24,294	81%	19%
2-Year, 2-Hour, 31.5 mm	2,133	20,567	90%	10%
1-Year, 11.5-Hour, 35 mm	704	6,152	89%	11%

Event Depth (mm)	WEPP-Estimated Hillslope Sediment Yield [1](Acre Feet / mi^2)	HEC-6T-Estimated Total Sediment Yield [1](Acre Feet / mi^2)	WEPP-Estimated Hillslope Sediment Yield (T/Ha)	HEC-6T-Estimated Total Sediment Yield (T/Ha)
100-Year, 6-Hour, 97.1 mm	0.090	0.243	0.415	1.122
10-Year, 6-Hour, 62.3 mm	0.054	0.139	0.251	0.642
5/17/1995, 74.9 mm	0.032	0.097	0.147	0.450
2-Year, 6-Hour, 40.8 mm	0.013	0.070	0.062	0.323
2-Year, 2-Hour, 31.5 mm	0.006	0.059	0.028	0.273
1-Year, 11.5-Hour, 35 mm	0.002	0.018	0.009	0.082

[1]Assumed sediment density = 0.97 g/cm^3 = average measured bulk density of all streambed sediment samples collected 9/00

Event Depth (mm)	Estimated Runoff Yield (m^3)	WEPP-Estimated Hillslope Sediment Concentration (mg/L)	HEC-6T-Estimated Total Sediment Concentration (mg/L)
100-Year, 6-Hour, 97.1 mm	37,842	826	2,232
10-Year, 6-Hour, 62.3 mm	18,359	1,029	2,632
5/17/1995, 74.9 mm	16,599	668	2,039
2-Year, 6-Hour, 40.8 mm	7,708	605	3,152
2-Year, 2-Hour, 31.5 mm	7,054	302	2,916
1-Year, 11.5-Hour, 35 mm	23,550	30	261

Table 4. Comparison of WEPP-Estimated Cumulative Sediment Yields and HEC-6T Estimated Sediment Yields for the Mower Ditch at Station GS02

Watershed: Mower Ditch (GS02) — *Drainage Area (Ha):* 68.9

Event Depth (mm)	WEPP-Estimated Cumulative Sediment Yield (kg)	HEC-6T Estimated Net Sediment Yield to GS02 (kg)	Portion of Net Yield Attributed to Channel Erosion (%)	Portion of Yield Attributed to Hillslope Erosion (%)
100-Year, 6-Hour, 97.1 mm	32,593	61,112	47%	53%
10-Year, 6-Hour, 62.3 mm	8,961	6,459	0%	100%
5/17/1995, 74.9 mm	9,715	6,238	0%	100%
2-Year, 6-Hour, 40.8 mm	780	1,724	55%	45%
2-Year, 2-Hour, 31.5 mm	186	708	74%	26%
1-Year, 11.5-Hour, 35 mm	9	252	96%	4%

Event Depth (mm)	WEPP-Estimated Hillslope Sediment Yield [1](Acre Feet / mi^2)	HEC-6T-Estimated Total Sediment Yield [1](Acre Feet / mi^2)	WEPP-Estimated Hillslope Sediment Yield (T/Ha)	HEC-6T-Estimated Total Sediment Yield (T/Ha)
100-Year, 6-Hour, 97.1 mm	0.102	0.192	0.473	0.887
10-Year, 6-Hour, 62.3 mm	0.028	0.020	0.130	0.094
5/17/1995, 74.9 mm	0.031	0.020	0.141	0.091
2-Year, 6-Hour, 40.8 mm	0.002	0.005	0.011	0.025
2-Year, 2-Hour, 31.5 mm	0.0006	0.002	0.003	0.010
1-Year, 11.5-Hour, 35 mm	0.00003	0.001	0.0001	0.004

[1]Assumed sediment density = 0.97 g/cm^3 = average measured bulk density of all streambed sediment samples collected 9/00

Event Depth (mm)	Estimated Runoff Yield (m^3)	WEPP-Estimated Hillslope Sediment Concentration (mg/L)	HEC-6T-Estimated Total Sediment Concentration (mg/L)
100-Year, 6-Hour, 97.1 mm	26,586	1,226	2,299
10-Year, 6-Hour, 62.3 mm	8,537	1,050	757
5/17/1995, 74.9 mm	13,531	718	461
2-Year, 6-Hour, 40.8 mm	2,206	354	782
2-Year, 2-Hour, 31.5 mm	860	216	824
1-Year, 11.5-Hour, 35 mm	979	9	258

Table 5. Comparison of WEPP-Estimated Cumulative Sediment Yields and HEC-6T Estimated Sediment Yields for Woman Creek at Station (GS01)

Watershed: Woman Creek at Indiana Street (GS01) *Drainage Area (Ha):* *438.5*

Event Depth (mm)	WEPP-Estimated Cumulative Sediment Yield (kg)	HEC-6T Estimated Net Sediment Yield to GS01 (kg)	Portion of Net Yield Attributed to Channel Erosion (%)	Portion of Yield Attributed to Hillslope Erosion (%)
100-Year, 6-Hour, 97.1 mm	234,423	94,979	0%	100%
10-Year, 6-Hour, 62.3 mm	67,661	28,091	0%	100%
5/17/1995, 74.9 mm	51,982	19,416	0%	100%
2-Year, 6-Hour, 40.8 mm	10,829	6,520	0%	100%
2-Year, 2-Hour, 31.5 mm	5,656	3,792	0%	100%
1-Year, 11.5-Hour, 35 mm	3,888	2,854	0%	100%

Event Depth (mm)	WEPP-Estimated Hillslope Sediment Yield [1](Acre Feet / mi^2)	HEC-6T-Estimated Total Sediment Yield [1](Acre Feet / mi^2)	WEPP-Estimated Hillslope Sediment Yield (T/Ha)	HEC-6T-Estimated Total Sediment Yield (T/Ha)
100-Year, 6-Hour, 97.1 mm	0.116	0.047	0.535	0.217
10-Year, 6-Hour, 62.3 mm	0.033	0.014	0.154	0.064
5/17/1995, 74.9 mm	0.026	0.010	0.119	0.044
2-Year, 6-Hour, 40.8 mm	0.005	0.003	0.025	0.015
2-Year, 2-Hour, 31.5 mm	0.003	0.002	0.013	0.009
1-Year, 11.5-Hour, 35 mm	0.002	0.001	0.009	0.007

[1]Assumed sediment density = 0.97 g/cm^3 = average measured bulk density of all streambed sediment samples collected 9/00

Event Depth (mm)	Estimated Runoff Yield (m^3)	WEPP-Estimated Hillslope Sediment Concentration (mg/L)	HEC-6T-Estimated Total Sediment Concentration (mg/L)
100-Year, 6-Hour, 97.1 mm	146,537	1,600	648
10-Year, 6-Hour, 62.3 mm	49,309	1,372	570
5/17/1995, 74.9 mm	73,693	705	263
2-Year, 6-Hour, 40.8 mm	13,375	810	487
2-Year, 2-Hour, 31.5 mm	8,215	689	462
1-Year, 11.5-Hour, 35 mm	14,499	268	197

Table 6. Comparison of WEPP-Estimated Cumulative Sediment Yields and HEC-6T Estimated Sediment Yields for Walnut Creek at Station (GS03)

Watershed: Walnut Creek at Indiana Street (GS03) — *Drainage Area (Ha):* 610

Event Depth (mm)	WEPP-Estimated Cumulative Sediment Yield (kg)	HEC-6T Estimated Net Sediment Yield to GS03 (kg)	Portion of Net Yield Attributed to Channel Erosion (%)	Portion of Yield Attributed to Hillslope Erosion (%)
100-Year, 6-Hour, 97.1 mm	271,698	248,864	0%	100%
10-Year, 6-Hour, 62.3 mm	97,477	119,096	18%	82%
5/17/1995, 74.9 mm	92,589	127,627	27%	73%
2-Year, 6-Hour, 40.8 mm	22,051	108,155	80%	20%
2-Year, 2-Hour, 31.5 mm	9,439	130,167	93%	7%
1-Year, 11.5-Hour, 35 mm	4,162	75,273	94%	6%

Event Depth (mm)	WEPP-Estimated Hillslope Sediment Yield [1](Acre Feet / mi^2)	HEC-6T-Estimated Total Sediment Yield [1](Acre Feet / mi^2)	WEPP-Estimated Hillslope Sediment Yield (T/Ha)	HEC-6T-Estimated Total Sediment Yield (T/Ha)
100-Year, 6-Hour, 97.1 mm	0.096	0.088	0.445	0.408
10-Year, 6-Hour, 62.3 mm	0.035	0.042	0.160	0.195
5/17/1995, 74.9 mm	0.033	0.045	0.152	0.209
2-Year, 6-Hour, 40.8 mm	0.008	0.038	0.036	0.177
2-Year, 2-Hour, 31.5 mm	0.003	0.046	0.015	0.213
1-Year, 11.5-Hour, 35 mm	0.001	0.027	0.007	0.123

[1]Assumed sediment density = 0.97 g/cm^3 = average measured bulk density of all streambed sediment samples collected 9/00

Event Depth (mm)	Estimated Runoff Yield (m^3)	WEPP-Estimated Hillslope Sediment Concentration (mg/L)	HEC-6T-Estimated Total Sediment Concentration (mg/L)
100-Year, 6-Hour, 97.1 mm	254,271	1,069	979
10-Year, 6-Hour, 62.3 mm	88,653	1,100	1,343
5/17/1995, 74.9 mm	161,172	574	792
2-Year, 6-Hour, 40.8 mm	61,657	358	1,754
2-Year, 2-Hour, 31.5 mm	43,053	219	3,023
1-Year, 11.5-Hour, 35 mm	48,053	87	1,566

Table 7. Evaluation of Updated WEPP/HEC-6T Model Uncertainty by Comparison of Model Results with Measured Data

Watershed	Storm Date	Precipitation and Storm Duration (mm / hrs)	Measured Runoff (m^3)	Measured Sediment Yield (kg)	WEPP-Estimated Sediment Yield (kg)	HEC-6T-Estimated Sediment Yield (kg)	Model Yield Overestimation Factor
Mower Ditch	2/19/97	6.9mm / 6 hrs	211	0.39	84	19.2	49
Mower Ditch	4/3/97	4.1mm / 3 hrs	261	7	0	21.1	3
SID	4/30/99	18.5mm / 14 hrs	5,648	73	0	165	2
SID	8/1/99	32mm / 15.5 hrs	1,790	77	5,781	3,590	47
SID	5/17/95	74.9mm / 11.5 hrs	18,823	1,449	11,091	33,851	23

Watershed	Storm Date	Measured TSS Concentration (mg/L)	Model-Estimated Concentration (mg/L)	Model Concentration Overestimation Factor
Mower Ditch	2/19/97	1.6	117	73
Mower Ditch	4/3/97	30	80.2	3
SID	4/30/99	13	14	1
SID	8/1/99	37	780	21
SID	5/17/95	77	2,017	26

Note: The Total Suspended Solids (TSS) sample for the 5/17/95 storm in the SID was collected on the rising limb of the runoff hydrograph preceding the peak discharge. Therefore, the sediment yield calculated from the TSS concentration under-represents the measured total sediment yield.

80

Table 8. Comparison of Total Suspended Solids Concentrations for Paired Samples Collected by Manual Depth Integrated Sampling (US DH48 Sampler) and an Automatic Sampler (ISCO 2700) With a Fixed-Point Sample Intake

Gaging Station	Date	Time	Collection Method	TSS (mg/L)	Sample ID
GS10	8/9/01	9:37	DH-48	442	01D1239-003.002
GS10	8/9/01	9:47	ISCO 2700	528	01D1239-004.002
SW093	8/9/01	10:07	DH-48	388	01D1239-001.002
SW093	8/9/01	10:08	ISCO 2700	377	01D1239-002.002

Table 9. Erosion Plot and GS42 Sample Data Collected for AME Erosion Modeling in 2001

Gaging Station or Plot Type	Date	Precipitation[1] (mm)	TSS Concentration MG/L	Volume Water Collected (L)	Sediment Yield (kg)	Erosion Rate (T/Ha)	Runoff Coefficient
CLIPPED	5/7/01	20.6	63	3.73	0.0002	8.39E-05	0.01
NATURAL	5/7/01	20.6	266	16.21	0.0043	1.55E-03	0.03
CLIPPED	5/20/01	8.25	No Sample	1.5	-	-	0.01
NATURAL	5/20/01	8.25	52	4.5	0.0002	8.40E-05	0.02
CLIPPED	5/29/01	6.25	180	1.5	0.0003	9.69E-05	0.01
NATURAL	5/29/01	6.25	250	1.5	0.0004	1.35E-04	0.01
CLIPPED	7/8/01	4.92	6,140	24.4	0.0060	2.13E-03	0.18
NATURAL	7/8/01	4.92	379	15.7	0.1496	5.37E-02	0.11
GS42	5/7/01	20.6	65	14.36	5.3	3.16E-04	0.09
GS42	7/8/01	4.92	No Sample	0	0	0	0.00
1. Rainfall obtained from Site Surface Water Monitoring Group - Preliminary Data Subject to Revision							
a. Rain on 5/5/01 produced sample collected on 5/7/01.							
b. Rainfall on 5/17 - 5/19 produced sample collected on 5/20/01.							
c. Rain on 5/27 - 5/29 produced sample collected 5/29/01.							
d. Rain on 7/8/01 produced sample collected 7/10/01, with no corresponding sample at GS42.							

81

Table 10. Comparison of Road Re-vegetation Scenarios for 100-year, 6-hour, 97.1-mm Storm

Watershed	Road Revegetation Scenario	Sediment Yield (kg)	Runoff (m^3)	Estimated Pu-239,240 Yield (pCi)	Estimated Pu-239,240 Concentration (pCi/L)	Estimated Am-241 Yield (pCi)	Estimated Am-241 Concentration (pCi/L)
SID	Dual Track Bike Paths, No Added Topsoil	87,687	40,000	6.38E+08	15.95	1.02E+08	2.56
	Complete Road Revegetation, No Added Topsoil	87,422	40,493	6.24E+08	15.40	9.92E+07	2.45
	Complete Road Revegetation, With Added Topsoil	88,149	40,371	6.19E+08	15.34	9.90E+07	2.45
	Existing Conditions	84,474	38,086	5.74E+08	15.07	9.09E+07	2.39
Woman Creek	Dual Track Bike Paths, No Added Topsoil	128,824	143,586	2.24E+08	1.48	3.62E+07	0.25
	Complete Road Revegetation, No Added Topsoil	122,535	141,543	2.20E+08	1.48	3.31E+07	0.23
	Complete Road Revegetation, With Added Topsoil	69,341	144,262	9.97E+07	0.67	1.81E+07	0.13
	Existing Conditions	94,979	146,537	1.80E+08	1.23	3.38E+07	0.23
Walnut Creek	Dual Track Bike Paths, No Added Topsoil	300,124	189,195	1.48E+08	0.78	5.51E+07	0.29
	Complete Road Revegetation, No Added Topsoil	292,874	182,018	1.45E+08	0.80	5.40E+07	0.30
	Complete Road Revegetation, With Added Topsoil	298,225	188,363	1.47E+08	0.78	5.46E+07	0.29
	Existing Conditions	248,864	254,271	1.60E+08	0.63	6.43E+07	0.25

Note: Values are for outlets of each watershed: SID at station SW027, Woman Creek at Indiana Street (GS01), and Walnut Creek at Indiana Street (GS03).

Table 11. Comparison of WEPP-Estimated 100-Year Annual Average Erosion Rates for the SID Watershed for Re-vegetation of Roads

HILLSLOPE WITH ROAD	HILLSLOPE AREA	AVERAGE ANNUAL SOIL LOSS	EROSION RATES FOR ROAD RE-VEGETATION TYPES			EROSION RATE % REDUCTION FOR RE-VEGETATION TYPES		
			RECLAIMED GRASSLAND	RECLAIMED GRASSLAND WITH TOPSOIL	DUAL TRACK BIKE PATH	RECLAIMED GRASSLAND	RECLAIMED GRASSLAND WITH TOPSOIL	DUAL TRACK BIKE PATH
(SEE COLOR CODING BELOW)	(hectares)	(Metric tons/ha)	(Metric tons/ha)	(Metric tons/ha)	(Metric tons/ha)	(%)	(%)	(%)
6	0.052	4.359	2.242	1.713	2.242	48.6%	60.7%	48.6%
10	1.217	0.284	0 279	0.19	0.279	1.9%	33.2%	1.9%
11	0.07	8.553	1.586	1.153	1.586	81.5%	86.5%	81.5%
12	0.855	0.743	0.255	0.262	0.255	65.7%	64.7%	65.7%
13	3.664	0.382	0.143	0.162	0.143	62.5%	57.6%	62.5%
14	2.433	0.278	0.264	0.253	0.264	4.9%	8.9%	4.9%
15	5.005	0.880	0.309	0.413	0.309	64.9%	53.1%	64.9%
16	4.246	0.429	0.424	0.414	0.429	1.3%	3.6%	0.1%
17	0.166	2.334	1.54	1.217	1.54	34.0%	47.9%	34.0%
18	8.508	0.545	0.419	0.384	0.419	23.1%	29.5%	23.1%
19	3.522	0.374	0.364	0.282	0.364	2.8%	24.7%	2.8%
20	6.672	0.466	0.454	0.45	0.467	2.6%	3.5%	-0.2%

100-Year Annual Average Yield Summary

		YIELD BY ROAD RE-VEGETATION TYPE (Metric Tons/H			AVERAGE PERCENT REDUCTION IN YIELD (%)		
ROAD TYPE COLOR CODING	PRESENT YIELDS (Metric Tons/Yr)	RECLAIMED GRASSLAND	RECLAIMED GRASSLAND WITH TOPSOIL	DUAL TRACK BIKEPATH	RECLAIMED GRASSLAND	RECLAIMED GRASSLAND WITH TOPSOIL	DUAL TRACK BIKEPATH
IMPROVED ROADS	0.83	0.23	0.17	0.23	72.4%	79.4%	72.4%
HILLSLOPES WITH IMPROVED ROADS	9.56	7.01	6.66	7.03	26.7%	30.3%	26.5%
HILLSLOPES WITH UNIMPROVED ROADS	4.77	4.65	4.23	4.74	2.6%	11.5%	0.8%
OVERALL AVERAGE YIELDS AND % REDUCTIONS	2.80	2.26	2.02	2.57	40.6%	57.0%	29.5%

Table 12. Comparison of WEPP-Estimated 100-Year Annual Average Erosion Rates for the Woman Creek Watershed for Re-vegetation of Roads

HILLSLOPE	HILLSLOPE AREA (hectares)	AVERAGE ANNUAL SOIL LOSS (tonnes/ha)	EROSION RATES FOR ROAD RE-VEGITATION TYPES: RECLAIMED GRASSLAND (Metric tons/ha)	DUAL TRACK BIKE PATH (Metric tons/ha)	RECLAIMED GRASSLAND WITH TOPSOIL (Metric tons/ha)	EROSION RATE % REDUCTION FOR RE-VEGITATION TYPES: RECLAIMED GRASSLAND (%)	DUAL TRACK BIKE PATH (%)	RECLAIMED GRASSLAND WITH TOPSOIL (%)
9	16.677	0.307	0.167	0.2	0.158	45.6%	34.9%	48.5%
10	0.115	5.352	0.804	0.976	0.065	85.0%	81.8%	98.8%
11	0.149	4.003	0.564	0.675	0.146	85.9%	83.1%	96.4%
12	0.155	5.841	0.791	0.959	0.215	86.5%	83.6%	96.3%
13	0.107	4.482	0.655	0.784	0.048	85.4%	82.5%	98.9%
17	6.357	0.249	0.074	0.105	0.072	70.3%	57.8%	71.1%
20	0.482	2.824	0.271	0.353	0.034	90.4%	87.5%	98.8%
21	0.259	8.446	1.216	1.418	0.257	85.6%	83.2%	97.0%
23	5.35	0.411	0.149	0.176	0.141	63.7%	57.2%	65.7%
24	0.113	5.142	0.737	0.89	0.037	85.7%	82.7%	99.3%
25	15.538	0.538	0.326	0.364	0.337	39.4%	32.3%	37.4%
27	14.755	0.573	0.339	0.38	0.354	40.8%	33.7%	38.2%
28	4.575	0.202	0.163	0.138	0.124	19.3%	31.7%	38.6%
29	0.658	0.138	0.03	0.035	0.032	78.3%	74.6%	76.8%
31	3.167	0.297	0.132	0.141	0.125	55.6%	52.5%	57.9%
33	35.793	0.195	0.196	0.196	0.196	0.0%	0.0%	0.0%
34	29.137	0.228	0.087	0.105	0.098	61.8%	53.9%	57.0%
35	31.08	0.152	0.069	0.077	0.067	54.6%	49.3%	55.9%
44	7.037	0.18	0.179	0.179	-	0.6%	0.6%	-
46	16.12	0.484	0.278	0.327	0.307	42.6%	32.4%	36.6%
49	0.266	7.763	1.158	1.351	0.114	85.1%	82.6%	98.5%
50	2.194	0.206	0.092	0.083	0.124	55.3%	59.7%	39.8%

100-Year Annual Average Yield Summary

ROAD TYPE COLOR CODING	PRESENT YIELDS (Metric Tons/Yr)	YIELD BY ROAD REVEGITATION TYPE (Metric Tons/Ha): RECLAIMED GRASSLAND	DUAL TRACK BIKEPATH	RECLAIMED GRASSLAND WITH TOPSOIL	AVERAGE PERCENT REDUCTION IN YIELD: RECLAIMED GRASSLAND	DUAL TRACK BIKEPATH	RECLAIMED GRASSLAND WITH TOPSOIL
IMPROVED ROADS	8.79	1.21	1.44	0.19	86.3%	83.6%	97.9%
HILLSLOPES WITH IMPROVED ROADS	55.54	32.94	36.49	32.46	40.7%	34.3%	41.5%

Table 13. Comparison of WEPP-Estimated 100-Year Annual Average Erosion Rates for the Walnut Creek. Watershed for Re-vegetation of Roads

			EROSION RATES FOR ROAD RE-VEGITATION TYPES			EROSION RATE % REDUCTION FOR RE-VEGITATION TYPES		
HILLSLOPE WITH ROAD	HILLSLOPE AREA	EXISTING AVERAGE ANNUAL SOIL LOSS	RECLAIMED GRASSLAND	RECLAIMED GRASSLAND WITH TOPSOIL	DUAL TRACK BIKE PATH	RECLAIMED GRASSLAND	RECLAIMED GRASSLAND WITH TOPSOIL	DUAL TRACK BIKE PATH
	(hectares)	(tonnes/ha)	(Metric tons/ha)	(Metric tons/ha)	(Metric tons/ha)	(%)	(%)	(%)
6	7.052	0.418	0 17	0.17	0.212	59.3%	59.3%	49 3%
7	0.085	7.907	0.064	1.459	1.055	99.2%	81.5%	86.7%
8	0.114	7.614	0.047	1.355	0.94	99.4%	82.2%	87.7%
10	12 788	0 195	0 183	0 183	0.179	6 2%	6.2%	8 2%
13	13.112	0 173	0 122	0.092	0.129	29.5%	46.8%	25.4%
14	0.192	4.425	0.038	0.038	0.479	99.1%	99.1%	89.2%
15	15 411	0.204	0.105	0.107	0.115	48.5%	47.5%	43 6%
24	7.394	0.569	0.455	0.462	0.46	20.0%	18.8%	19.2%
26	5.234	0.444	0.345	0.351	0.348	22.3%	20.9%	21 6%
31	0.398	0.507	0.001	0.012	0.012	99.8%	97.6%	97.6%
35	1.349	0.5	0.387	0.399	0.414	22.6%	20.2%	17.2%
36	3.928	0 442	0.276	0.28	0 282	37.6%	36.7%	36 2%
41	0.158	4.132	0.048	0.246	0.206	98.8%	94.0%	95.0%
42	1.844	0.479	0.173	0.221	0.235	63.9%	53.9%	50.9%
44	2.952	0.398	0 246	0.257	0.281	38.2%	35.4%	29 4%
45	5.638	0.52	0.228	0.238	0.227	56.2%	54.2%	56 3%
46	5.226	0.707	0.376	0.381	0.389	46.8%	46.1%	45 0%
53	0.443	0.672	0.003	0.047	0.039	99.6%	93.0%	94.2%
57	12.859	0.262	0.043	0 104	0.11	83 6%	60.3%	58 0%
58	6.662	0.486	0.236	0.259	0.233	51.4%	46.7%	52.1%
59	0.888	0.323	0.165	0 126	0.197	48.9%	61.0%	39 0%
60	5.832	0.657	0.204	0.254	0.243	68.9%	61.3%	63.0%
61	0.257	13.714	0.105	1.888	1.335	99.2%	86.2%	90 3%
63	4.41	0.592	0.217	0.285	0.289	63.3%	51.9%	51 2%
69	1.472	0.673	0.002	0.43	0.666	99.7%	36.1%	1 0%
71	0.16	5.804	0.039	0.414	0.285	99.3%	92.9%	95.1%
73	2.03	3.279	0.406	1 059	0.449	87.6%	67.7%	86 3%
74	0.444	6.977	0.984	1.339	0.065	85.9%	80.8%	99.1%
76	1.368	0.693	0.121	0 229	0.182	82.5%	67.0%	73 7%
78	1.629	0.5	0.101	0.203	0.166	79.8%	59.4%	66 8%
81	0.117	6.565	0.037	0.508	0.351	99.4%	92.3%	94.6%
86	3.08	0 324	0.139	0.177	0.167	57.1%	45.4%	48 5%
88	2.926	0.631	0.325	0 244	0.235	48.5%	61.3%	62 8%
99	15.293	0.184	0.117	0.093	-	36.4%	49.5%	-

100-Year Annual Average Yield Summary

		YIELD BY ROAD REVEGITATION TYPE (Metric Tons/He			AVERAGE PERCENT REDUCTION IN YIELD		
ROAD TYPE COLOR CODING	PRESENT YIELDS (Metric Tons/Yr)	RECLAIMED GRASSLAND	RECLAIMED GRASSLAND WITH TOPSOIL	DUAL TRACK BIKEPATH	RECLAIMED GRASSLAND	RECLAIMED GRASSLAND WITH TOPSOIL	DUAL TRACK BIKEPATH
IMPROVED ROADS	8.8	0.1	1.0	0.8	99.3%	89.0%	91.2%
HILLSLOPES WITH IMPROVED ROADS	54	23	26	24	56.4%	51.3%	55.9%
HILLSLOPES WITH UNIMPROVED ROADS	3.5	2.3	3.0	3.3	32.8%	14.7%	6.2%

85

Table 14. Comparison of HEC-6T Estimated Reservoir Trap Efficiencies Compared to Theoretical Trap Efficiencies

Pond A-4					
Event Depth Return Period and Duration	**Inflow Yield to Pond (m^3)**	**[2]Ratio of Pond Capacity to Inflow Yield**	**Trap Efficiency [1](USBR, 1982) (%)**	**HEC-6T Estimated Total Sediment Trapped (%)**	**HEC-6T Estimated Sand Trapped (%)**
35mm, 1-Year, 11.5 Hour	6,963	17.47	97%	32%	100%
31.5mm, 2-Year, 2-Hour	15,545	7.82	94%	25%	100%
40.8mm, 2-Year, 6-Hour	21,287	5.71	92%	24%	100%
74.9mm, May 17, 1995	46,661	2.61	89%	25%	99%
62.3mm, 10-Year, 6-Hour	31,308	3.89	90%	22%	100%
97.1mm, 100-Year, 6-Hour	92,443	1.32	87%	21%	85%
Pond B-5					
Event Depth Return Period and Duration	**Inflow Yield to Pond (m^3)**	**[3]Ratio of Pond Capacity to Inflow Yield**	**Trap Efficiency [1](USBR, 1982) (%)**	**HEC-6T Estimated Total Sediment Trapped (%)**	**HEC-6T Estimated Sand Trapped (%)**
35mm, 1-Year, 11.5 Hour	4,824	18.82	97%	58%	100%
31.5mm, 2-Year, 2-Hour	21,505	4.22	91%	59%	100%
40.8mm, 2-Year, 6-Hour	27,115	3.35	90%	58%	100%
74.9mm, May 17, 1995	50,434	1.80	89%	59%	100%
62.3mm, 10-Year, 6-Hour	15,158	5.99	93%	37%	100%
97.1mm, 100-Year, 6-Hour	86,262	1.05	85%	49%	100%
Pond C-1					
Event Depth Return Period and Duration	**Inflow Yield to Pond (m^3)**	**[4]Ratio of Pond Capacity to Inflow Yield**	**Trap Efficiency [1](USBR, 1982) (%)**	**HEC-6T Estimated Total Sediment Trapped (%)**	**HEC-6T Estimated Sand Trapped (%)**
35mm, 1-Year, 11.5 Hour	8,393	0.15	74%	72%	100%
31.5mm, 2-Year, 2-Hour	3,026	0.41 to 0.58	80 - 81%	54%	100%
40.8mm, 2-Year, 6-Hour	5,804	0.22 to 0.40	76 - 80%	54%	100%
74.9mm, May 17, 1995	28,703	0.04 to 0.14	63 - 72%	63%	100%
62.3mm, 10-Year, 6-Hour	39,981	0.03 to 0.19	60 - 75%	64%	99%
97.1mm, 100-Year, 6-Hour	85,903	0.01 to 0.09	50 - 68%	60%	95%

1. US Bureau of Reclamation, 1982, Reservoir Sedimentation, Technical Guideline for Bureau of Reclamation, US Department of the Interior, Denver, Colorado, p.17.

2. Pond A-4 Volume is approximately 121,700 m^3 (98.6 Acre-Feet)

3. Pond B-5 Volume is approximately 90,800 m^3 (73.6 Acre-Feet)

4. Pond C-1 capacity is the range between the capacity at zero flow and the average between the capacity at zero flow and the capacity at peak flow based on HEC-6T predicted water levels and 1992 capacity study.

- EG&G, September 30, 1992, Final Summary Report Detention Pond Capacity Study, Merrick and Company, Denver, CO.

Table 15. Evaluation of Detention Pond Removal Scenarios for the Walnut Creek and Woman Creek Watersheds

Walnut Creek Ponds Scenarios	Precipitation Event (return period, duration, depth (mm))	Estimated Sediment Yield (kg)	Estimated Runoff Yield (m^3)	Estimated Pu-239,240 Yield (pCi)	Estimated Pu-239,240 Concentration (pCi/L)	Estimated Am-241 Yield (pCi)	Estimated Am-241 Concentration (pCi/L)	Pu-239,241 Yield Increase Without Ponds (%)	Am-241 Yield Increase Without Ponds (%)
Current Conditions	1-year, 11.5 hour, 35 mm	75,273	48,053	4.44E+07	0.92	5.28E+07	1.10	0%	0%
Only A4&B5 Ponds	1-year, 11.5 hour, 35 mm	76,939	48,053	3.92E+07	0.82	4.54E+07	0.94	-12%	-14%
Only B5 Pond	1-year, 11.5 hour, 35 mm	53,088	48,053	3.47E+07	0.72	4.28E+07	0.89	-22%	-19%
No ponds	1-year, 11.5 hour, 35 mm	38,142	47,901	2.56E+07	0.53	2.97E+07	0.62	-42%	-44%
Current Conditions	100-year, 6 hour, 35 mm	248,864	254,271	1.60E+08	0.63	6.43E+07	0.25	0%	0%
Only A4&B5 Ponds	100-year, 6 hour, 35 mm	246,194	254,271	1.75E+08	0.69	6.52E+07	0.26	9%	1%
Only B5 Pond	100-year, 6 hour, 35 mm	299,288	254,271	1.49E+08	0.59	5.14E+07	0.20	-7%	-20%
No ponds	100-year, 6 hour, 35 mm	296,561	252,278	1.80E+08	0.72	7.17E+07	0.28	13%	12%
Woman Creek Scenarios	Precipitation Event (return period, duration, depth (mm))	Estimated Sediment Yield (kg)	Estimated Runoff Yield (m^3)	Estimated Pu-239,240 Yield (pCi)	Estimated Pu-239,240 Concentration (pCi/L)	Estimated Am-241 Yield (pCi)	Estimated Am-241 Concentration (pCi/L)	Pu-239,241 Yield Increase Without Ponds (%)	Am-241 Yield Increase Without Ponds (%)
Current Conditions	1-year, 11.5 hour, 35 mm	2,854	14,499	4.97E+05	0.03	8.46E+04	0.01	0%	0%
No C-1 Pond	1-year, 11.5 hour, 35 mm	3,845	14,529	7.36E+05	0.05	1.47E+05	0.01	48%	74%
Current Conditions	100-year, 6 hour, 35 mm	94,979	146,537	1.80E+08	1.23	3.38E+07	0.23	0%	0%
No C-1 Pond	100-year, 6 hour, 35 mm	136,323	146,537	2.17E+08	1.48	3.32E+07	0.23	20%	-2%

Table 16. Evaluation of Upper SID Connection to Woman Creek Via an Engineered Channel and Resulting Truncated SID

Woman Creek at GS01

SID to Woman Creek Scenario	Precipitation Event (return period, duration, depth(mm))	Estimated Sediment Yield (kg)	Estimated Runoff Yield (m^3)	Estimated Pu-239,240 Yield (pCi)	Estimated Pu-239,240 Concentration (pCi/L)	Estimated Am-241 Yield (pCi)	Estimated Am-241 Concentration (pCi/L)	Pu-239,240 Yield Increase With SID Inflow (%)	Am-241 Yield Increase With SID Inflow (%)
Current Conditions at GS01	1-year, 11.5 hour, 35mm	2,854	14,499	4.97E+05	0.03	8.46E+04	0.0058	0%	0%
SID Routed to Woman Creek	1-year, 11.5 hour, 35mm	4,193	17,448	1.44E+06	0.08	1.51E+05	0.009	189%	78%
Current Conditions at GS01	100-year, 6 hour, 97.1mm	94,979	146,537	1.80E+08	1.23	3.38E+07	0.231	0%	0%
SID Routed to Woman Creek	100-year, 6 hour, 97.1mm	114,520	161,155	3.31E+08	2.05	3.41E+07	0.212	84%	1%

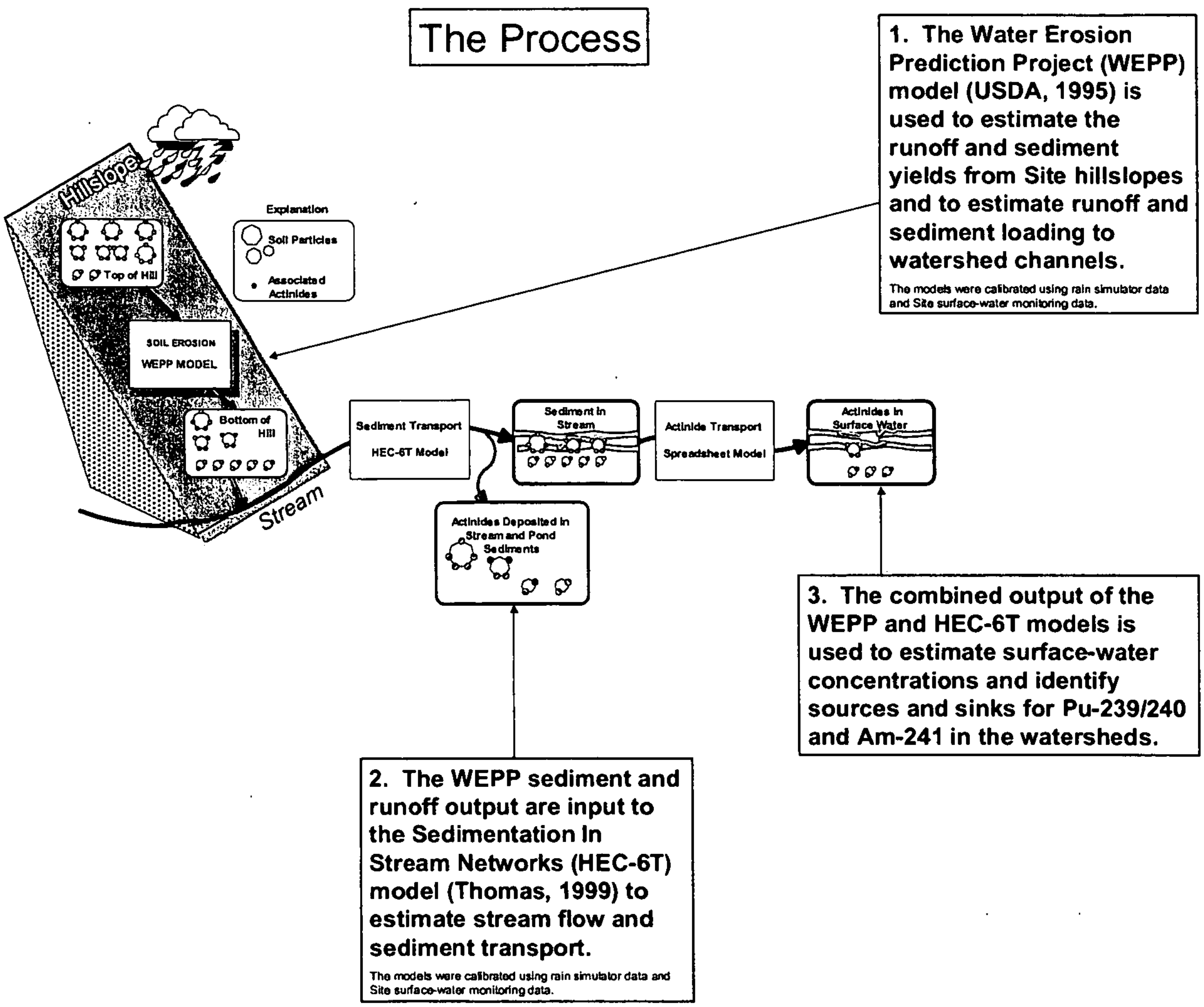
Truncated SID at SW027

SID Scenario	Precipitation Event (return period, duration, depth(mm))	Estimated Sediment Yield (kg)	Estimated Runoff Yield (m^3)	Estimated Pu-239,240 Yield (pCi)	Estimated Pu-239,240 Concentration (pCi/L)	Estimated Am-241 Yield (pCi)	Estimated Am-241 Concentration (pCi/L)	Pu-239,240 Yield Increase With SID Inflow (%)	Am-241 Yield Increase With SID Inflow (%)
Current Conditions at SW027	1-Year 11.5-Hour, 35mm	6,152	3,943	4.38E+05	0.11	1.28E+05	0.0325	0%	0%
Truncated SID	1-Year 11.5-Hour, 35mm	472	415	4.01E+05	0.97	6.60E+04	0.159	-9%	-48%
Current Conditions at SW027	100-Year 6-Hour, 97.1mm	84,474	38,086	5.74E+08	15.07	9.09E+07	2.3876	0%	0%
Truncated SID	100-Year 6-Hour, 97.1mm	43,227	24,742	6.00E+08	24.25	9.73E+07	3.932	5%	7%

FIGURES

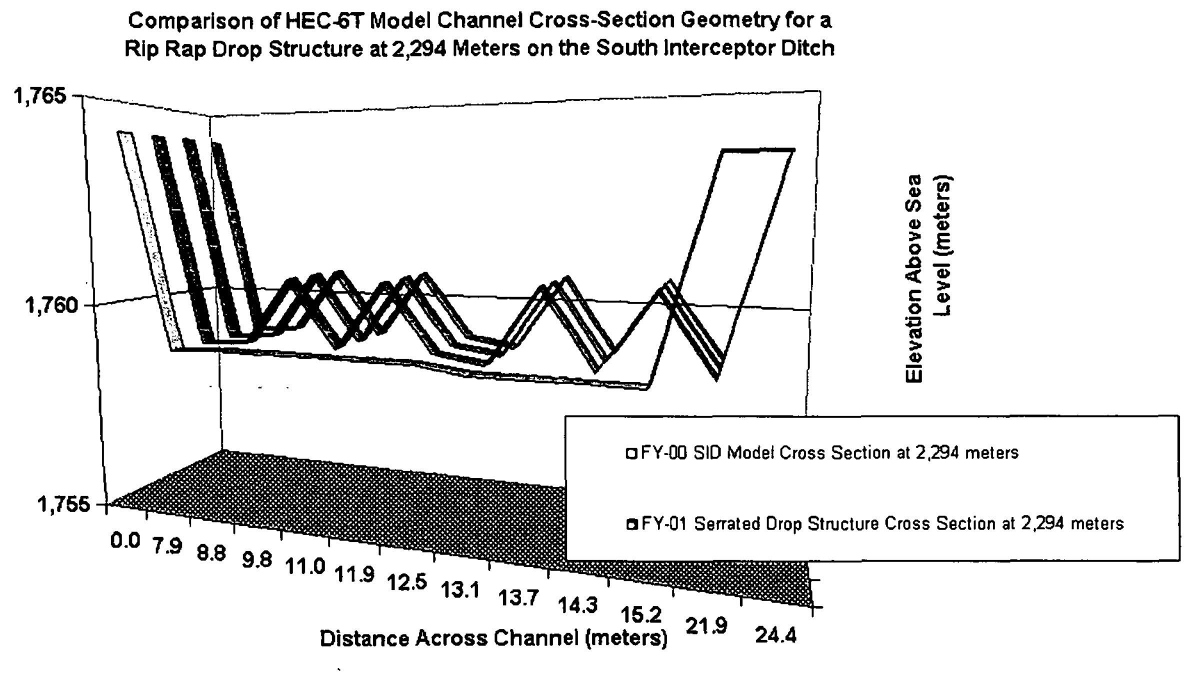
89

Figure 2. Schematic Diagram of the AME Erosion, Sediment and Actinide Transport Modeling Process



91

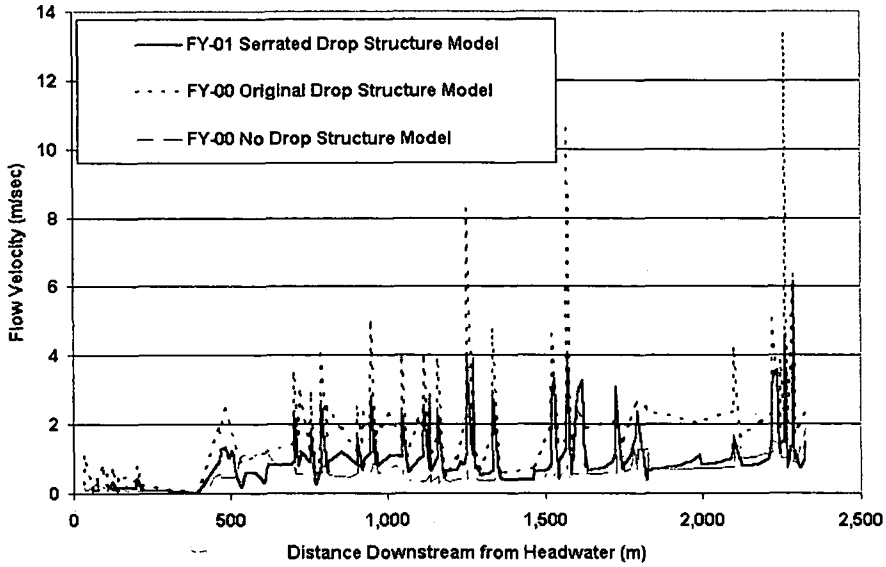
Figure 5. Comparison of HEC-6T Cross Section Geometry for a Typical Rip Rap Drop Structure On the SID



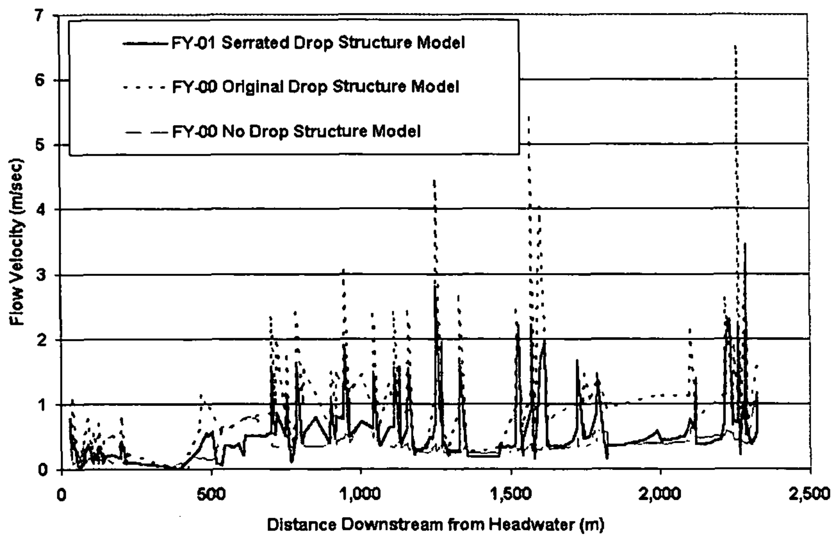
94

Figure 6. Comparison of Estimated Flow Velocities at Peak Discharge for the SID HEC-6T Models–31.5-mm and 97.1-mm Events

Comparison of Estimated Surface-Water Velocity at Peak Discharge
for South Interceptor Ditch HEC-6T Models (97.1mm, 100-Year Event)

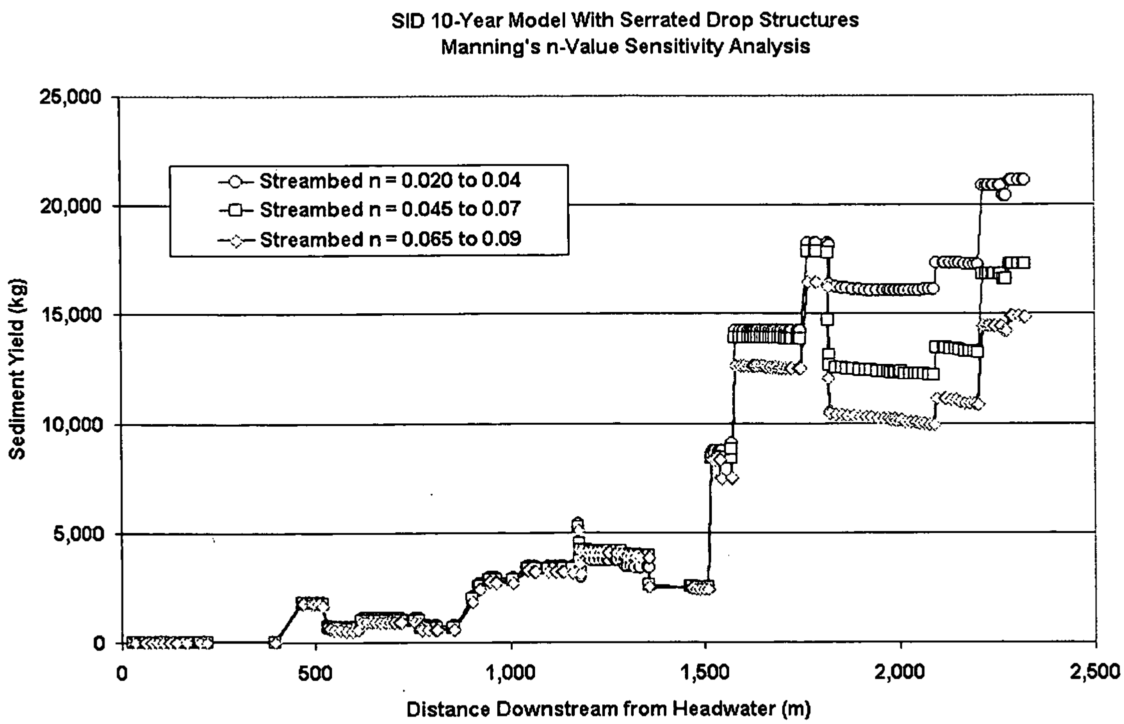


Comparison of Estimated Surface-Water Velocity at Peak Discharge
for South Interceptor Ditch HEC-6T Models (31.5mm, 2-Year Event)



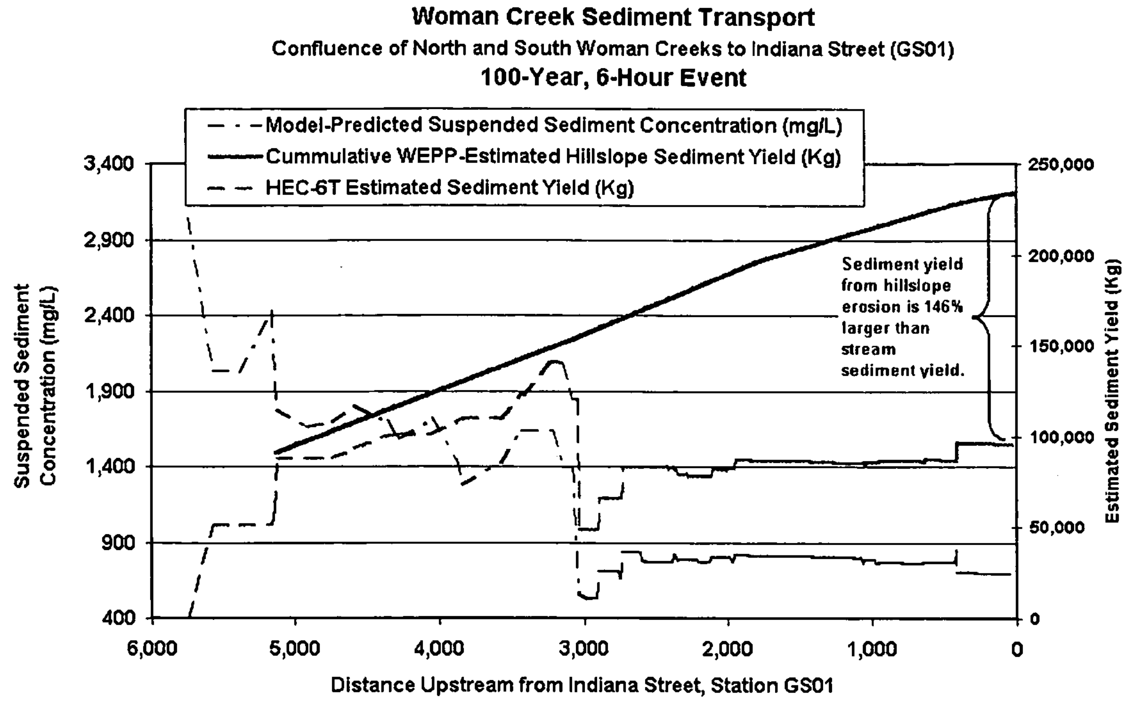
95

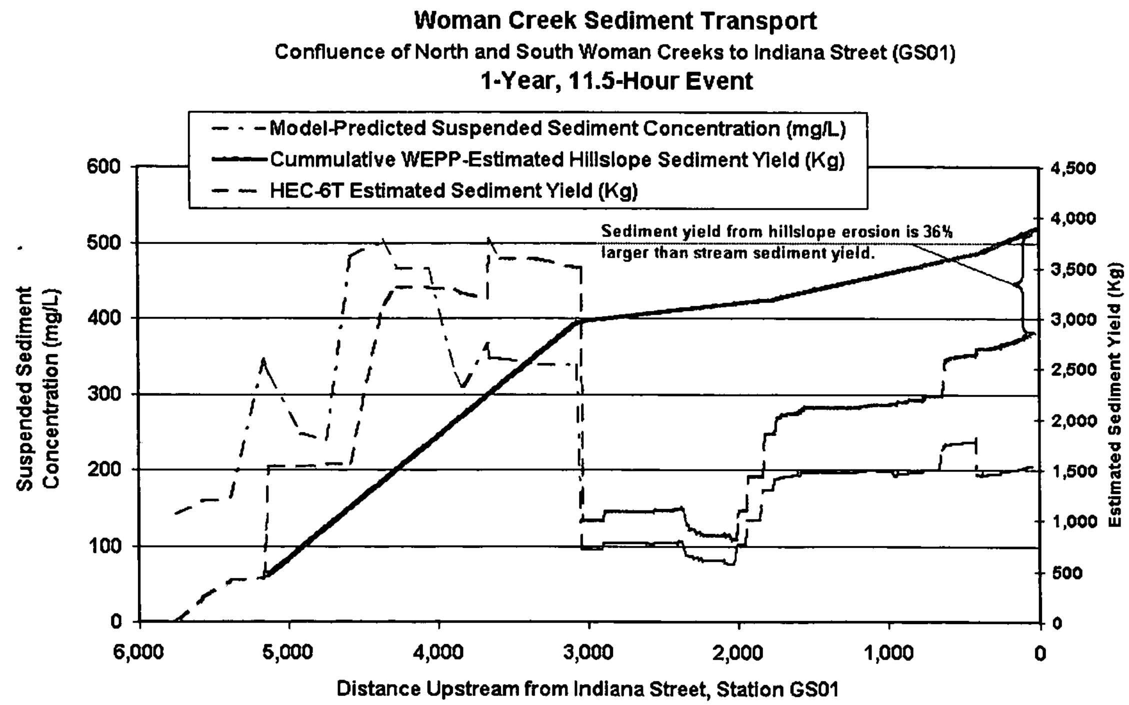
Figure 7. Results of Manning's n-Value Sensitivity Analysis for the FY01 Serrated Drop Structure HEC-6T Model for the SID–62.3-mm, 10-Year Event



96

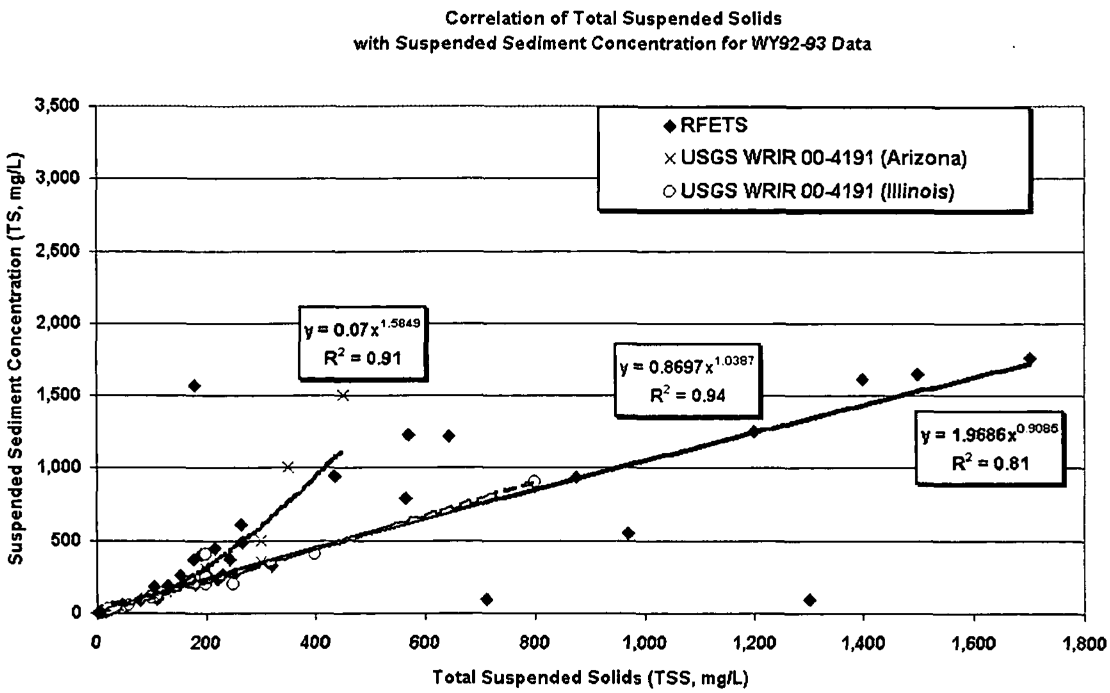
Figure 9. Comparison of Hillslope and Channel Erosion Sediment Yields in Woman Creek.





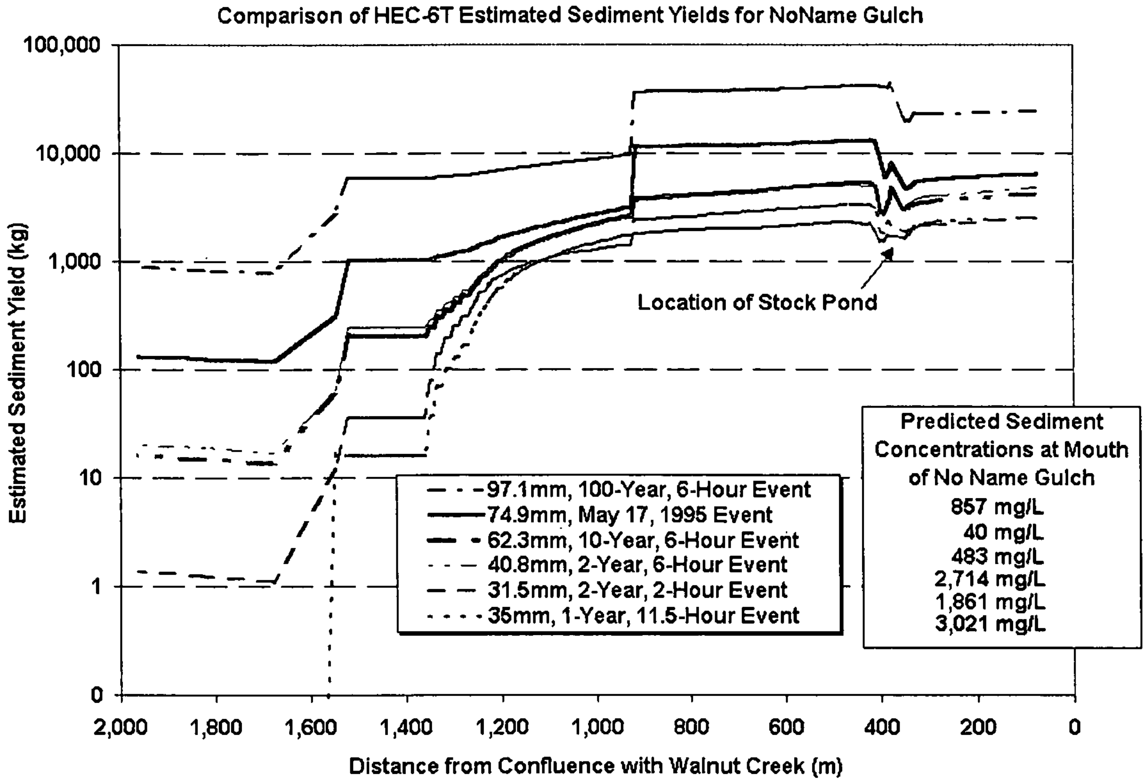
98

Figure 10. Correlation of Total Suspended Solids and Suspended Sediment Concentrations for Historical Surface Water Monitoring Data



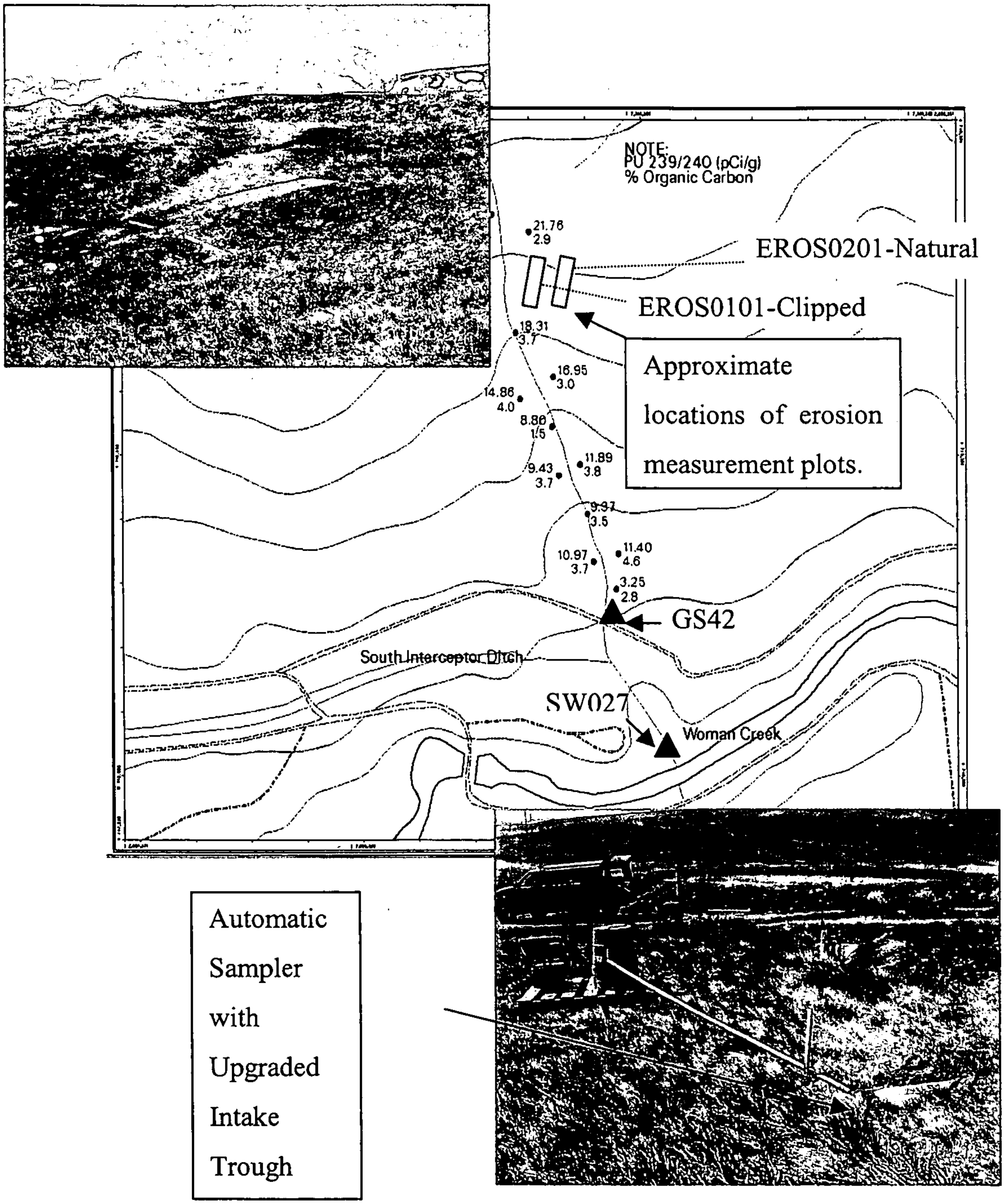
99

Figure 11. Comparison of HEC-6T Estimated Sediment Yields for Updated No Name Gulch Model



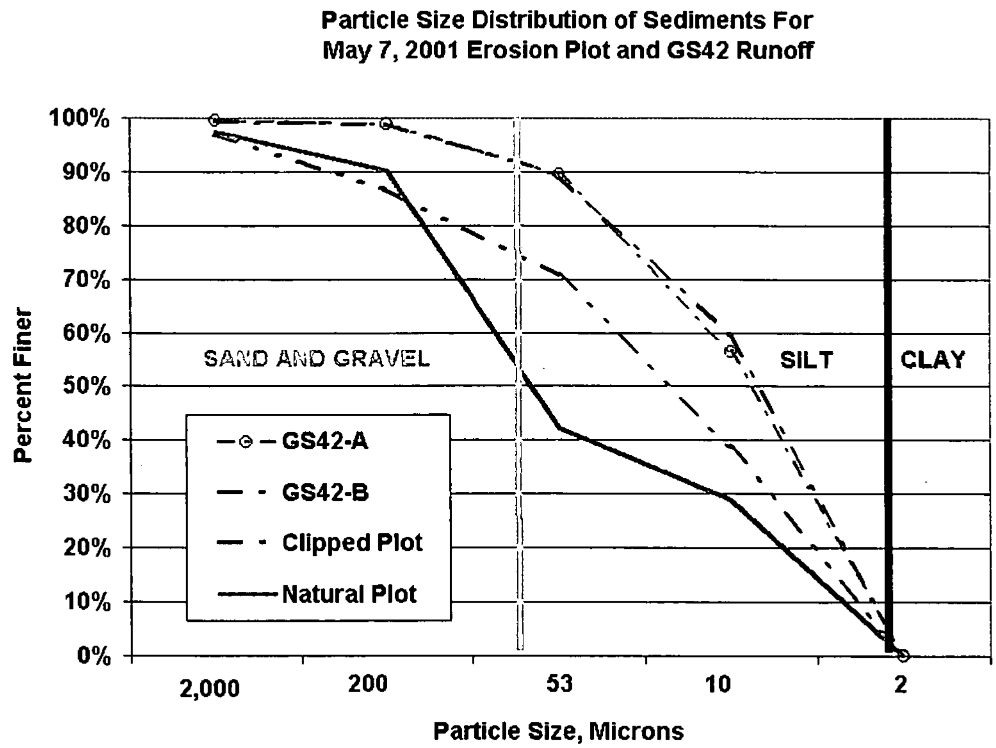
100

Figure 12. Location and Photographs of Erosion Plots and GS42 Monitoring Station

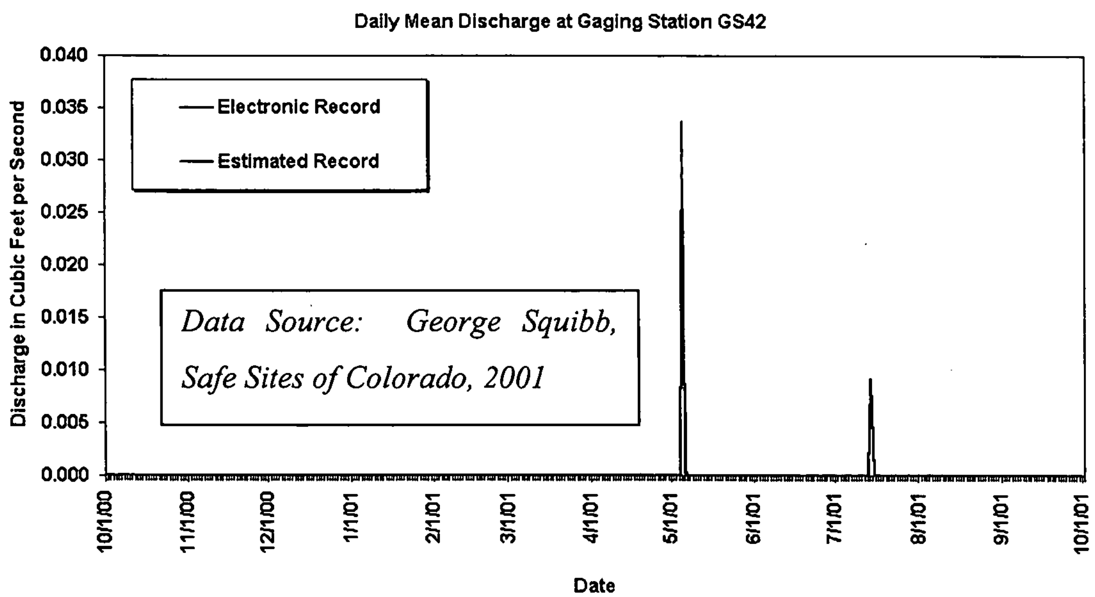


101

Figure 13. Comparison of Particle Size Distributions for May 7, 2001 Runoff From Erosion Plots and the GS42 Drainage Basin and Water Year 2001 Daily Mean Discharge Hydrograph for GS42

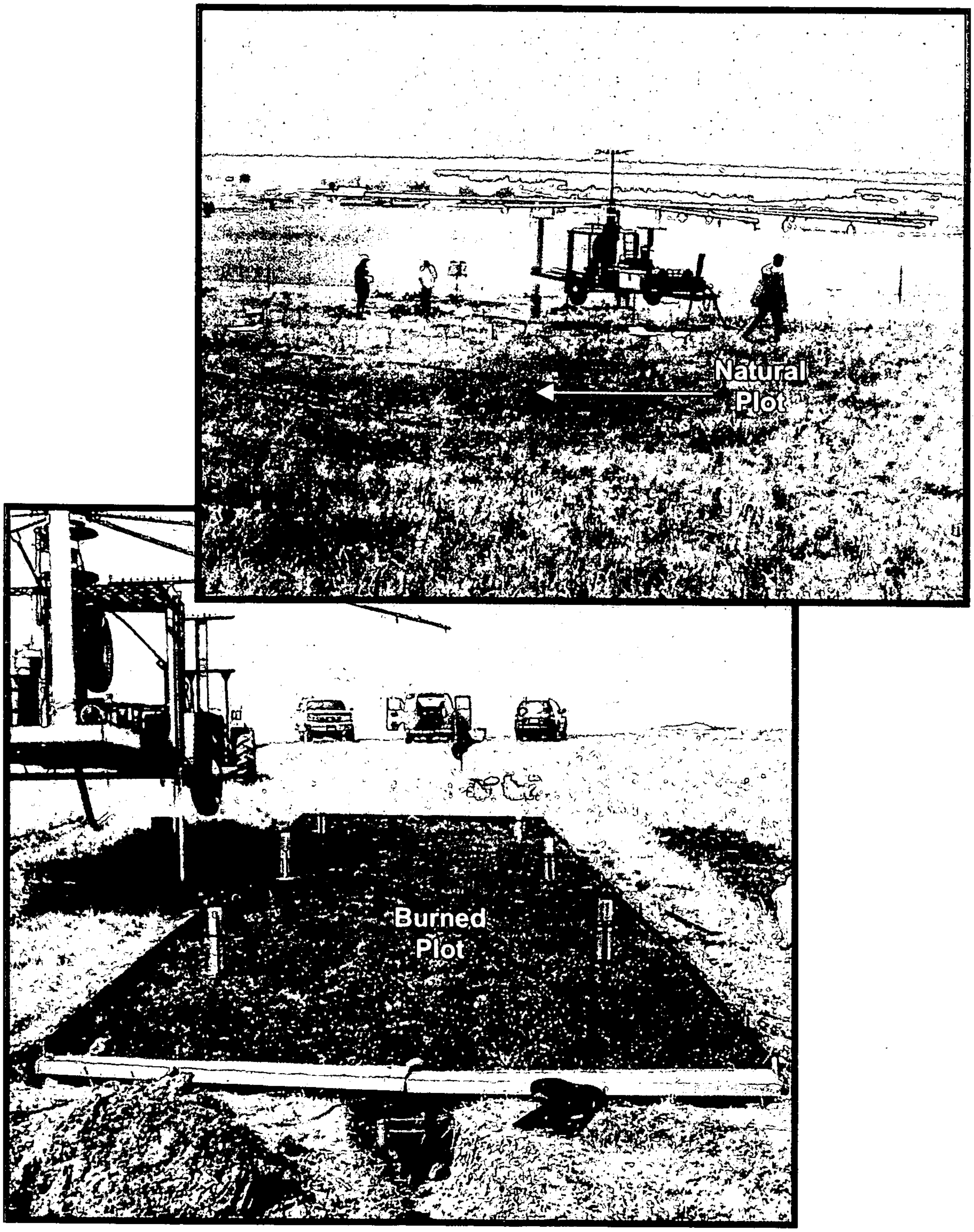


Data Source: Dr. James F. Ranville, Colorado School of Mines, 2000-2001



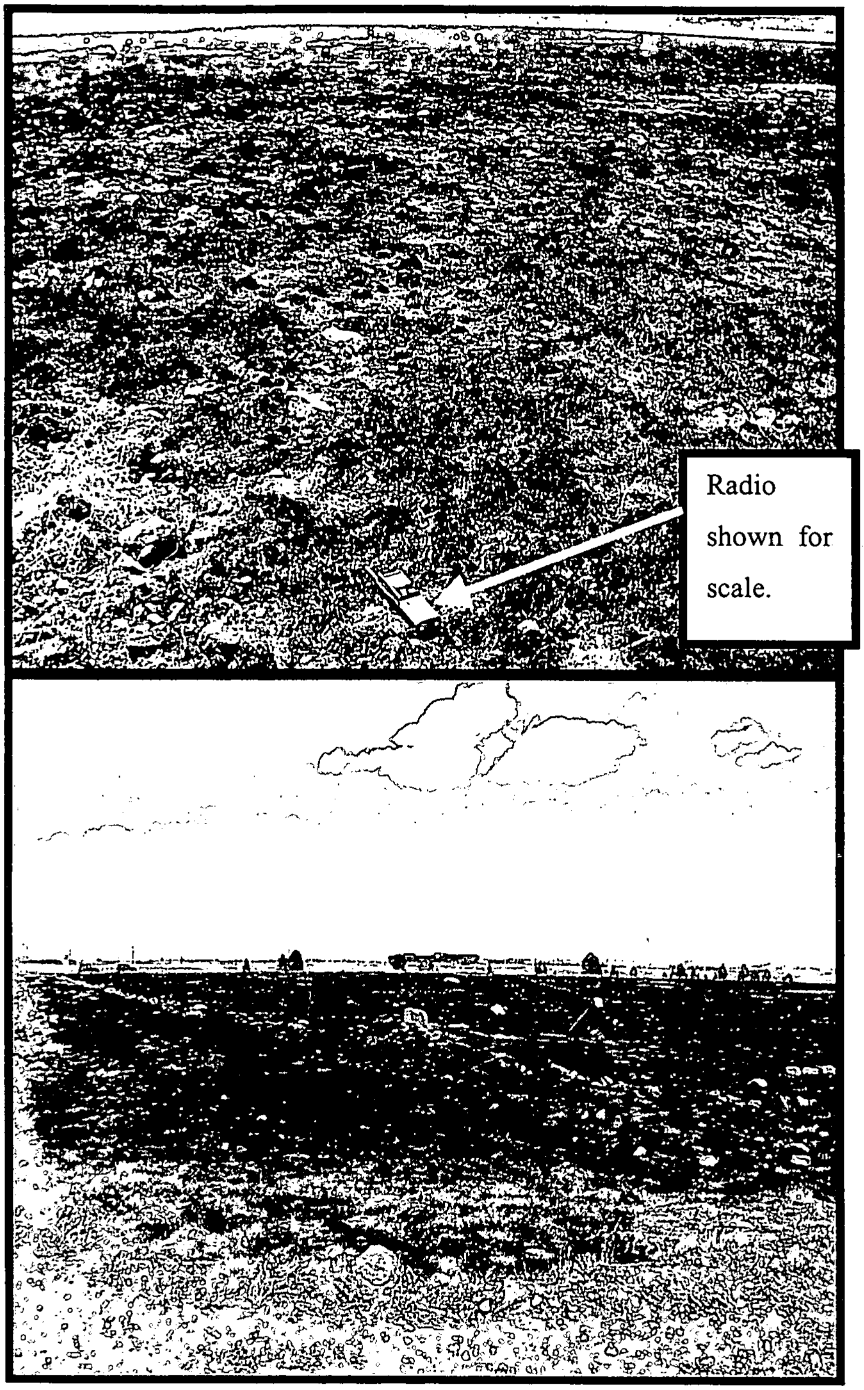
102

Figure 14. Colorado State University Erosion Plots at the Hope Ranch Adjacent to the Site



103

Figure 21. Examples of Prescribed Burn Vegetation Cover



110

APPENDICES

APPENDIX A

Model Documentation and Appendices From 2000 Actinide Migration Evaluations Report (CD-ROM in Pocket)

APPENDIX B

Erratum for 2000 Report

This appendix contains corrected pages for replacement of erroneous text, tables, and figures in the August 2000 report: *Report on Soil Erosion/Surface Water Sediment Transport for the Actinide Migration Evaluation at the Rocky Flats Environmental Technology Site.* Other minor typographical errors have been identified but ignored.

137

1.0 Introduction

1.1 Purpose

This report presents results of the Actinide Migration Evaluation (AME) Soil Erosion and Surface Water Sediment Transport Modeling Project activities. The goal of the AME Modeling Project is to estimate and quantify actinide loading rates to surface water, in the short- and long-term, under the range of climatological and environmental conditions that may occur at the Site. The transport of soil by erosion and overland flow is modeled using the Watershed Erosion Prediction Project (WEPP) model (Flanagan and Livingston, 1995). The transport of sediments by surface water within Site drainage channels is estimated with the Sedimentation in Stream Networks (HEC-6T) model (Thomas, 1999).

The AME is investigating the mobility of plutonium-239/240 (Pu-239/240), americium-241 (Am-241), and uranium-234, 235, 238 (U) isotopes in the Site environment. The goal of the AME is to achieve the objectives contained in the AME Data Quality Objectives (DQO) document (Kaiser-Hill, 2000b).

These objectives are addressed by performing mathematical modeling of the actinide transport processes (identified as important contributors) in the Site environment. Current information suggests that actinide transport in sediments by overland flow (soil erosion) and in channeled surface water is an important transport mechanism that can impact surface-water quality in both the short- and long-term. The most efficient method for assessing contributions of soils and sediments to surface water loads of actinides is through the use of models. The current work is limited to consideration of transport in and by water.

Mathematical models were calibrated with measured data and then used to make predictions about potential future conditions. Extensive discussion of the calibration procedures and results are presented in Appendices A and C. After the calibration step, the model output data were compared to Site monitoring data to assess model performance. When reasonable modeling results were finally obtained and model calibration was confirmed, the results were used to draw conclusions about how soil erosion and sediment transport could affect Site water quality for current conditions.

1.2 Regulatory Framework

Surface water standards and action levels are established in the Rocky Flats Cleanup Agreement (DOE, 1996a). Surface water monitoring at the Site is performed in accordance with particle size distribution of water-stable aggregates in the soil (Rocky Mountain Remediation Services [RMRS], 1998a). The estimated activity of the erosion sediments were combined with the results of the sediment transport modeling and used to model: 1) effects of the present Site configuration and soil contaminant levels on surface water quality; and 2) effects of reduced soil actinide levels on surface water quality. Future Site configurations are planned to be modeled in fiscal year 2001 (FY01).

This report provides information and tools needed to determine actinide levels and management practices for Pu-239/240 and Am-241 in Site soils that will be protective of surface water quality in both the short- and long-term. The models created for this report can be used as planning tools for remediation of surface soils, long-term protection of surface water, watershed management, final Site configuration, and preparation of the risk assessment needed for Site regulatory closure.

This report includes the following:

- Descriptions of the three drainages that were modeled: Woman Creek, the SID, and Walnut Creek (Section 2);
- The conceptual model for surface transport of actinides and a description of soil erosion and sediment transport processes (Section 3);
- A discussion of the selection of the models and model components (Section 4);
- A description of the Site models and model data needs (Section 5);
- Descriptions of the steps taken to integrate the models and the modeling DQOs (Section 6);
- Results of hillslope erosion modeling, including predicted rates of movement for Pu-239/240 and Am-241 in surface soils (Section 7);
- Results of channel sediment transport modeling (Section 8);
- The results of the Pu-239/240 and Am-241 surface water transport modeling, including the effects of various soil cleanup levels on surface water concentrations of Pu-239/240 and Am-241 (Section 9);
- A description of modeling uncertainties (Section 10, supplemented in Appendix D);
- A project summary and description of future planned work (Section 11);
- References (Section 12);
- Erosion and actinide mobility maps (Figures at end of report);

to Woman Creek. In the past, the majority of water from Woman Creek was diverted into Mower Ditch. The diversion was shut off in 1997, and now water flows off Site in the natural Woman Creek channel to the Woman Creek Reservoir on the east side of Indiana Street.

Antelope Springs Gulch is a perennial feature that carries water from Antelope Springs, a large seep to the south of Woman Creek. It normally has base flow throughout the year. Antelope Springs Gulch flows into Woman Creek just upstream of Pond C-1.

The SID was constructed in 1980 to divert surface water runoff from the southern portion of the IA to Pond C-2 (Figure 1). It was originally designed to handle a 100-year precipitation event. Erosion, sedimentation, and encroachment of vegetation have reduced the SID's flow velocity and capacity (EG&G, 1992a). The SID was modeled as a separate drainage, because its flow is entirely contained by Pond C-2.

2.2 Walnut Creek

The Walnut Creek watershed area is approximately 3.7 mi^2 (9.6 square km^2)(Figure 1). The watershed is comprised of two perennial streams: South Walnut Creek and North Walnut Creek; and ephemeral to intermittent features known as No Name Gulch and the McKay Bypass Canal. The Present Landfill and the Landfill Pond are situated in the headwaters of No Name Gulch. The Landfill Pond does not discharge into the gulch. Flows in No Name Gulch result primarily from base flow and runoff from surrounding hillsides.

Water in the upper reaches of North Walnut Creek (northwest of the IA) is diverted to the McKay Bypass, which flows to the north of the Present Landfill. Until 1999, this water reentered the Walnut Creek drainage downstream of No Name Gulch. A diversion structure and pipeline were installed to route water to Great Western Reservoir, precluding flow from Walnut Creek. However, for this study the diversion is assumed to be absent. Water draining from the north side of the IA enters North Walnut Creek and is diverted by pipeline around Ponds A-1 and A-2 into A-3. Ponds A-1 and A-2 are used for spill control for the IA and do not discharge into the drainage. Pond A-3 is batch released to Pond A-4, which is batch discharged into the North Walnut Creek channel.

South Walnut Creek receives runoff from the IA, including the Central Avenue Ditch and a portion of the 903 Pad Area. The natural channel of South Walnut Creek has been greatly changed by construction in the IA during operation of the Site and the B-Series Detention Ponds in 1980 (Figure 1). Ponds B-1 and B-2 are normally off-line but are maintained at a level to keep sediments wet and are reserved for IA spill control. Water in Pond B-3 is batch discharged to B-groups based on the Site soil map (Figure 5) and/or by changes in vegetation type based on the Site's vegetation map (Figure 7). Soil and vegetation parameters used in the model are discussed in detail in Appendix A. Figure 9 through Figure 12 sh ow the OFE boundaries and slope transects for each hillslope, in each watershed.

The slope of each OFE was determined using geographic information systems (GIS). Linear transects, perpendicular to the topography, were drawn electronically from the top to the bottom of each OFE on 2-foot interval contour coverages, such that the transects visually represent the overall topography of the OFEs (

Figure 7 through Figure 9). Next, GIS techniques were used to provide several instantaneous slope values at points on the transects. The transect slope values were averaged laterally across each OFE to provide data that describe the average land surface profile in each OFE. Hillslope and OFE dimensions, soil types, and vegetation/habitat types are listed in Table 3 through Table 5 for each watershed.

The hillslope lengths and areas were also determined using the linear transects on each hillslope (see Appendix A and

Figure 7 through Figure 9). Typically, three or more transects were drawn on the hillslopes, and the average length was determined to represent the hillslope length. The computed hillslope lengths were divided into the hillslope areas, as determined by GIS methods, to compute the hillslope widths. This was done to preserve the measured hillslope lengths, because slope length is a sensitive erosion modeling parameter. Although the hillslopes are irregularly shaped in real space, WEPP forms rectangular hillslopes in virtual space for the model computations. The WEPP hillslopes are two-dimensional surfaces that vary in length and width and along the vertical dimension (the slope) but do not vary laterally across the slope. The AME project team developed techniques to convert WEPP output back into data that can be mapped using GIS to show the distribution of erosion across the watersheds (Appendix B).

The hillslopes were delineated to provide reasonable resolution for estimation of runoff and erosion without making the model unnecessarily complex. Some of the hillslope lengths exceed the recommended lengths for WEPP. Therefore, contributors to WEPP at the ARS Southwest Watershed Research Center in Tucson, Arizona, were consulted to review the hillslope and channel delineations. Their assessment concluded that the hillslopes and channels were reasonable (J. Stone and M. Weltz, personal communication, 1998). The effects of hillslope length on runoff and soil loss are shown in Appendix A. Mokhothu (1996) showed that

Table 4. Hillslope and Overland Flow Element Dimensions, Habitat Type, and Soil Type for the Walnut Creek Watershed WEPP Model, (continued)

Hillslope Number	OFE Number	Habitat Type	Surface Soil Type	Area (m^2)	Hillslope Width (m)	Hillslope Length (m)	OFE Length (m)
81	1	Improved Road	Improved road soil	1,180	10	118	118
84	1	Xeric Tall Grass Praine	Top-slope cobbly sandy loam				31
84	2	Xeric Tall Grass Praine	Side-slope clay loam				53
84	3	Mesic Mixed Grassland	Side-slope clay loam				210
84	4	Wet Meadow	Side-slope clay loam				297
84	5	Willow Riparian Shrubland	Bottom-slope clay loam	105,628	165	640	49
85	1	Xeric Tall Grass Prairie	Top-slope cobbly sandy loam				127
85	2	Mesic Mixed Grassland	Side-slope clay loam				136
85	3	Wet Meadow	Side-slope clay loam	51,676	155	333	21
86	1	Improved Road	Side-slope clay loam				28
86	2	Reclaimed Grassland	Improved road soil				60
86	3	Improved Road	Side-slope clay loam				10
86	4	Reclaimed Grassland	Side-slope clay loam				27
86	5	Mesic Mixed Grassland	Side-slope clay loam				244
86	6	Wet Meadow	Side-slope clay loam	30,800	77	400	31
87	1	Xeric Tall Grass Prairie	Side-slope clay loam	67,450	355	190	190
88	1	Reclaimed Grassland	Top-slope cobbly sandy loam				89
88	2	Reclaimed Grassland	Side-slope clay loam				23
88	3	Improved Road	Improved road soil				15
88	4	Reclaimed Grassland	Improved road soil				63
88	5	Smarsh	Side-slope clay loam	29,306	138	212	42
99	1	Improved Road	Improved road soil				134
99	2	Xeric Tall Grass Prairie	Top-slope cobbly sandy loam				29
99	3	Reclaimed Grassland	Top-slope cobbly sandy loam				50
99	4	Improved Road	Improved road soil				45
99	5	Willow Riparian Shrubland	Side-slope clay loam	15,293	426	36	12

(see description of the GIS model in Section B7). Again, these data are storm-event-specific.

5. Unitless "enrichment factors" were calculated to quantify the increased or decreased actinide activity level factor associated with a specific particle size range relative to a unit mass of typical hillslope material composed of mixed particle sizes (as provided by the GIS model described in point 4 above). These enrichment factors are the same for each watershed model. They were calculated using the Pu-239/240 and Am-241 versus mass distributions from the Colorado School of Mines (CSM) study (utilizing four particle size ranges) to redistribute the Pu-239/240 and Am-241 among HEC-6T's nine particle size ranges (RMRS, 1998d). Section B-10 describes the comparison of WEPP-estimated and measured particle size distributions and the particle size distribution of Pu-239/240 and Am-241 in Site soils. For each of the nine particle size ranges, the percent of total activity divided by the percent of total mass results in an enrichment factor that quantifies the relative affinity of Pu-239/240 and Am-241 for specific sizes of particles. An enrichment factor greater than one indicates that a unit mass of that particular particle size has an actinide concentration (activity per unit mass) that is greater than that of the "bulk" mixed size material. Similarly, an enrichment factor less than one indicates the specific particle size has an actinide concentration (activity per unit mass) that is less than that of the "bulk" mixed size material. Enrichment factors calculated and applied to this model are listed in Table B-5.

Table B-5. Particle Size Enrichment Factors

Particle Size Lower Bound (microns)	Particle Size Upper Bound (microns)	Particle Size Mass Distribution Cum Fraction	Particle Size Mass Fractions by Size Class	Am -241 Distribution Cum %	Fraction by Size Class	Am -241 Enrichment Factor	Pu-239/240 Distribution Cum %	Fraction by Size Class	Pu-239/240 Enrichment Factor
0	4	0.029	0.029	0.047	0.047	1.615	0.045	0.045	1.553
4	8	0.042	0.013	0.069	0.022	1.705	0.067	0.022	1.682
8	16	0.124	0.082	0.164	0.095	1.157	0.146	0.079	0.957
16	32	0.235	0.111	0.295	0.131	1.176	0.256	0.111	0.998
32	62	0.341	0.106	0.418	0.124	1.166	0.360	0.103	0.974
62	125	0.455	0.114	0.551	0.133	1.165	0.471	0.111	0.977
125	250	0.576	0.121	0.674	0.123	1.017	0.587	0.116	0.960
250	500	0.719	0.142	0.782	0.108	0.755	0.726	0.138	0.971
500	1,000	0.860	0.141	0.891	0.110	0.776	0.863	0.137	0.972
1,000	2,000	1.000	0.140	1.000	0.109	0.776	1.000	0.137	0.979

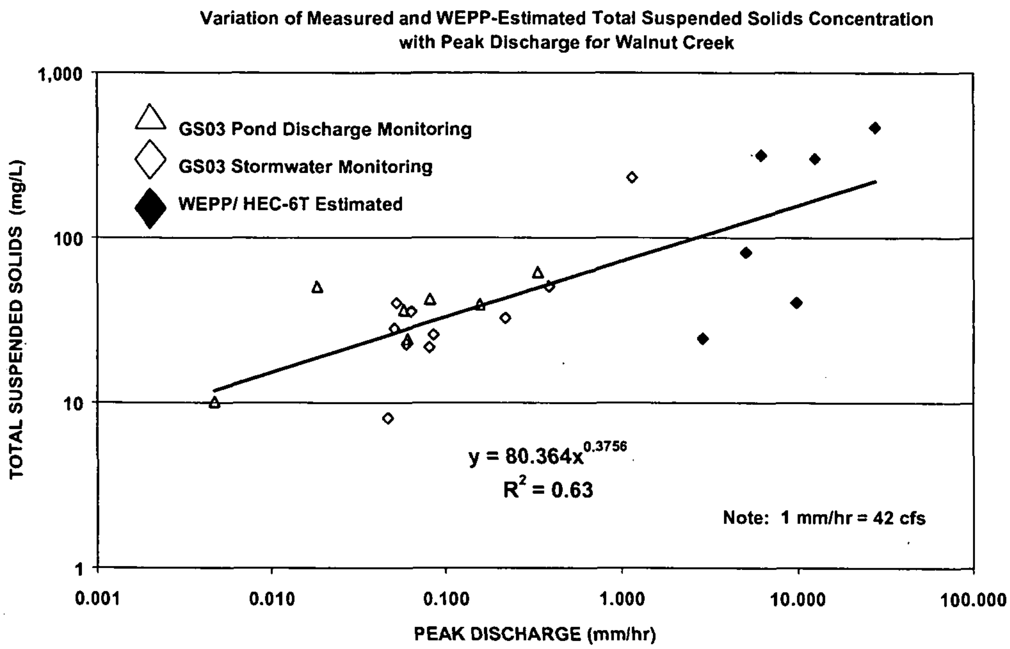
Table 10.- Summary of Woman Creek Average WEPP Runoff and Erosion

HILLSLOPE	MEAN ANNUAL PRECIPITATION	MEAN ANNUAL RAIN RUNOFF	MEAN ANNUAL SNOW RUNOFF	MEAN ANNUAL RUNOFF	AVERAGE SEDIMENT YIELD	TOTAL SEDIMENT YIELD	HILLSLOPE WIDTH	HILLSLOPE AREA	AVERAGE ANNUAL SOIL LOSS	AVERAGE SUSPENDED SOLIDS	RUNOFF COEFFICIENT
		(mm)	(mm)	(mm)	(kg/m)	(kg)	(m)	(hectares)	(tonnes/ha)	(mg/L)	
1	370	7.98	2.04	10.02	12.895	4,963	385	21.213	0.234	2,336	0.027
2	370	11.4	1.31	12.81	9.815	6,762	684	15.322	0.443	3,428	0.035
3	370	13.88	2.73	16.61	13.142	6,808	518	11.083	0.614	3,697	0.045
4	370	4.47	0.08	4.55	4.81	1,549	322	18.483	0.084	1,842	0.012
5	370	4.57	0.08	4.65	3.356	1,068	318	13.828	0.077	1,649	0.013
6	370	13.75	2.19	15.94	2.12	1,293	610	11.651	0.111	696	0.043
7	370	21.19	4.93	26.12	2.671	1,186	444	9.28	0.128	489	0.071
8	370	19.82	2.12	21.94	2.405	993	413	7.847	0.127	577	0.059
9	370	16.11	2.88	18.99	7.831	5,121	654	16.677	0.307	1,617	0.051
10	370	99.36	17.64	117	77.069	617	8	0.115	5.352	4,582	0.316
11	370	90.49	15.74	106.23	74.483	596	8	0.149	4.003	3,764	0.287
12	370	88.31	15.09	101.4	113.306	906	8	0.155	5.841	5,787	0.274
13	370	95.28	16.27	111.55	60.062	480	8	0.107	4.482	4,026	0.301
14	370	16.33	2.3	18.63	11.482	2,560	223	9.368	0.273	1,467	0.050
15	370	10.31	4.25	14.56	16.712	4,562	273	22.304	0.205	1,405	0.039
16	370	16.46	7.73	24.19	2.349	587	250	20.525	0.029	118	0.065
17	370	25.07	4.96	30.03	3.235	1,563	483	6.337	0.243	629	0.081
18	370	17.84	2.29	20.13	9.536	2,622	275	10.752	0.244	1,212	0.054
19	370	12.08	3.12	15.2	2.03	579	285	10.63	0.054	358	0.041
20	370	64.75	11.8	76.55	170.285	1,362	8	0.482	2.824	3,692	0.207
21	370	80.52	14.59	95.11	273.656	2,189	8	0.229	9.449	8,866	0.257
22	370	10.29	2.3	12.59	4.426	2,851	644	25.696	0.111	881	0.034
23	370	30.21	4.56	34.77	4.114	2,201	535	5.35	0.411	1,163	0.094
24	370	91.26	15.63	106.89	72.509	580	8	0.113	5.142	4,802	0.289
25	370	14.38	1.85	16.23	25.163	8,354	332	15.538	0.538	3,313	0.044
26	370	20.14	3.61	23.75	0.949	265	279	3.181	0.083	351	0.064
27	370	13.62	2.26	15.88	18.225	8,456	464	14.755	0.573	3,609	0.043
28	370	21.18	4.98	25.16	6.163	924	150	4.575	0.202	772	0.071
29	370	39.89	6.77	46.66	0.359	91	253	0.656	0.138	296	0.126
30	370	24.22	2.45	26.67	1.003	241	240	1.872	0.129	482	0.072
31	370	16.6	1.89	18.49	6.03	941	156	3.167	0.297	1,607	0.050
32	370	12.94	2.24	15.18	8.627	992	115	6.313	0.157	1,035	0.041
33	370	12.03	2.83	14.86	18.941	6,989	369	35.793	0.195	1,314	0.040
34	370	7.04	1.59	8.63	16.519	6,657	403	29.137	0.228	2,647	0.023
35	370	11.89	2.1	13.99	15.939	4,718	296	31.08	0.152	1,083	0.038
36	370	13.86	3.36	17.22	2.767	761	275	9.542	0.08	463	0.047
37	370	13.53	3.14	16.67	1.129	534	473	15.136	0.035	212	0.045
38	370	16.08	2.45	18.53	0.81	258	318	5.533	0.047	251	0.050
39	370	9.1	2.41	11.51	1.441	477	331	9.996	0.048	415	0.031
40	378	30.95	3	33.95	1.823	933	512	4.352	0.214	632	0.090
41	370	11.81	1.84	13.65	3.526	2,028	575	26.048	0.078	570	0.037
42	370	10.17	1.57	11.74	0.119	55	460	4.676	0.011	96	0.032
43	370	10.79	2.67	13.46	12.846	3,160	246	16.679	0.189	1,408	0.036
44	370	11.45	1.65	13.1	5.702	1,268	222	7.037	0.18	1,373	0.035
45	370	17.12	2.41	19.53	1.381	522	378	6.539	0.08	409	0.053
46	370	13.45	1.98	15.43	37.478	7,793	208	16.12	0.484	3,134	0.042
47	370	24.9	4.78	29.68	1.232	450	365	3.978	0.113	381	0.080
48	370	17.59	2.5	20.09	0.624	44	71	1.143	0.039	193	0.054
49	370	88.77	16.46	105.23	258.509	2,068	8	0.200	7.763	7,388	0.284
50	370	15.49	1.88	17.37	4.365	432	103	2.194	0.200	1,185	0.047

ESTIMATED ANNUAL WOMAN CREEK WATERSHED SEDIMENT YIELD (TONNES/HA)		0.221
ESTIMATED ANNUAL WOMAN CREEK WATERSHED SEDIMENT YIELD (TONS/ACRE)		0.099
ESTIMATED ANNUAL WOMAN CREEK WATERSHED EROSION DEPTH (mm)		0.025
ESTIMATED ANNUAL WOMAN CREEK RUNOFF COEFFICIENT		0.043

WOMAN CREEK LANDUSE	100-YEAR AVERAGE SEDIMENT YIELDS (TONNES/HA)	100-YEAR AVERAGE SUSPENDED SOLIDS (MG/L)	100-YEAR AVERAGE ANNUAL RUNOFF (MM)	100-YEAR AVERAGE ANNUAL RUNOFF COEFFICIENT	PERCENT CONTRIBUTION TO TOTAL SOIL LOSS
IMPROVED ROADS	5.35	5,364	102	0.220	8%
HILLSLOPES WITH IMPROVED ROADS	0.26	1,742	21	0.035	43%
GRAZED HILLSLOPES	0.26	2,590	10	0.025	19%
HILLSLOPES WITH MINIMAL DISTURBANCE	0.11	613	19	0.047	25%

Figure C- 11. Comparison of WEPP/HEC-6T Estimated Total Suspended Solids Concentrations with Measured Data



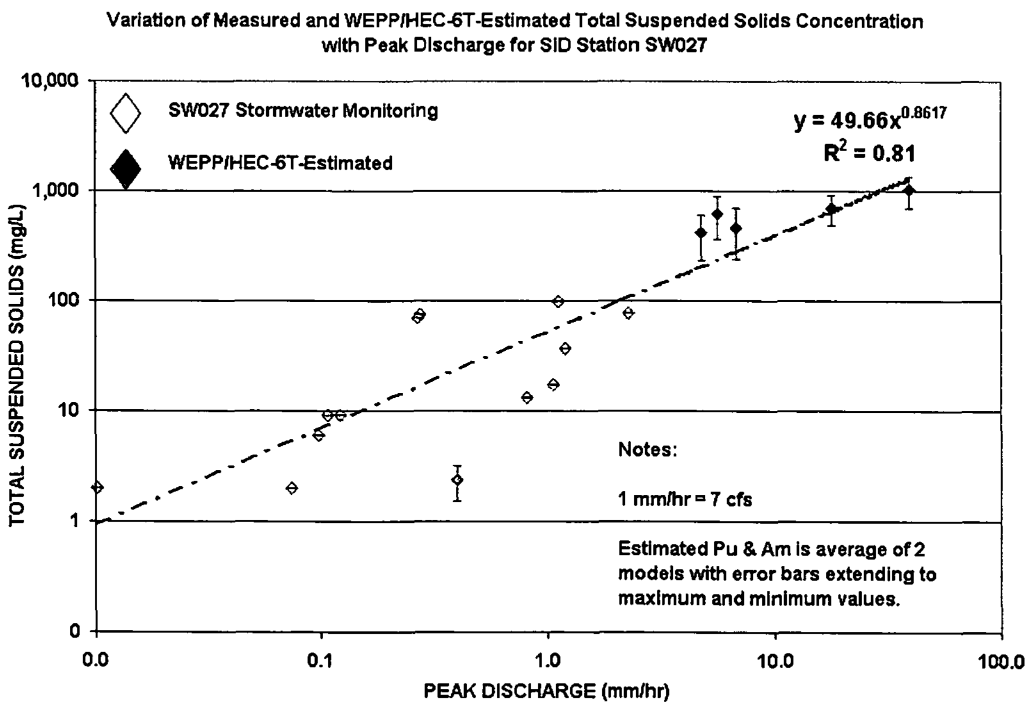
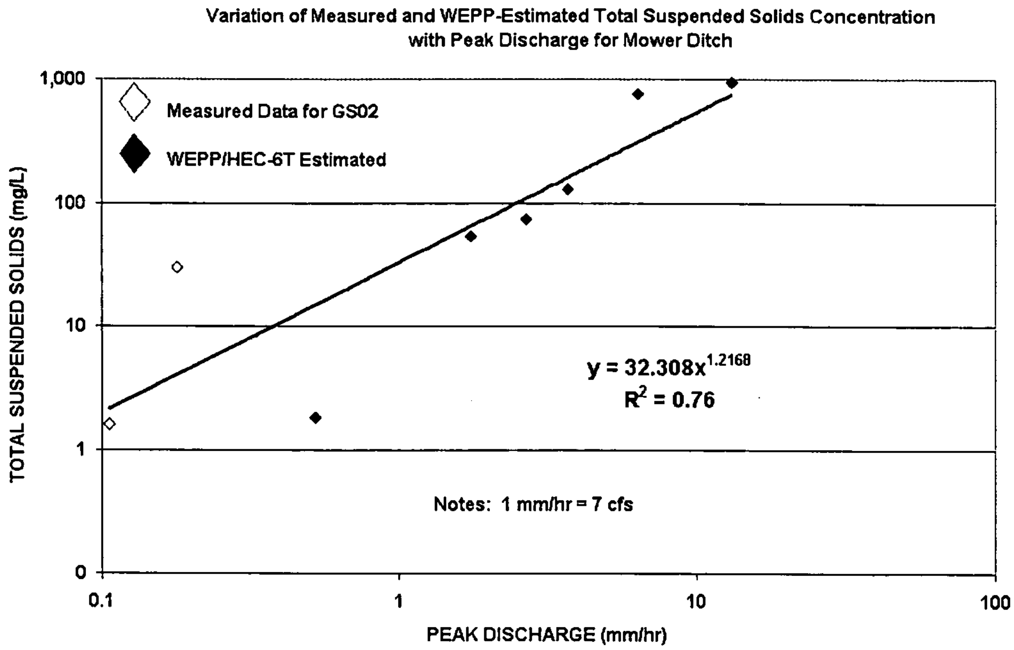
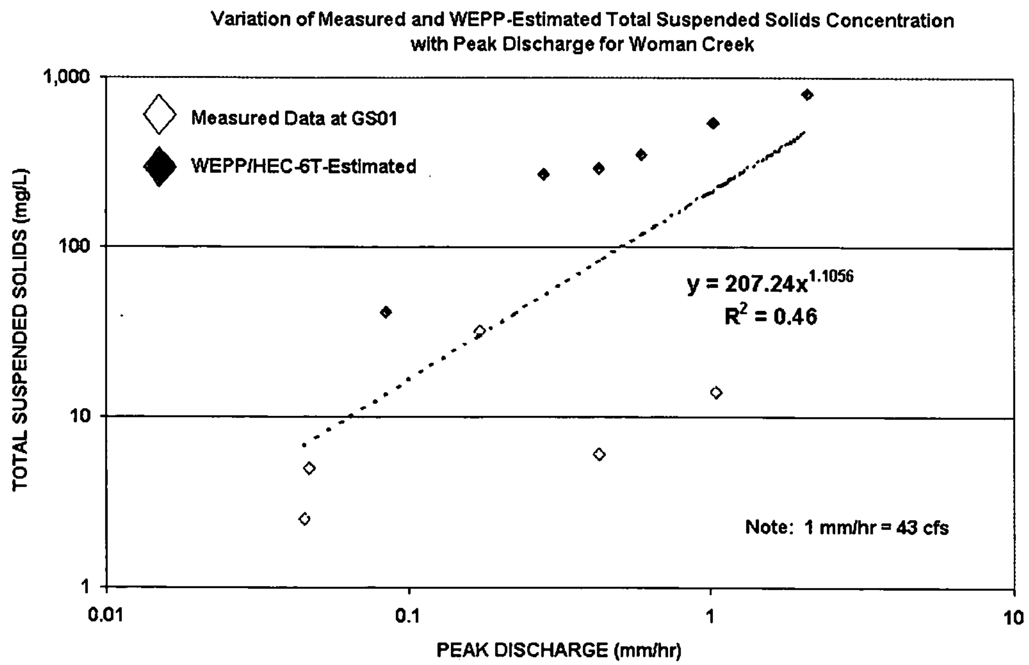


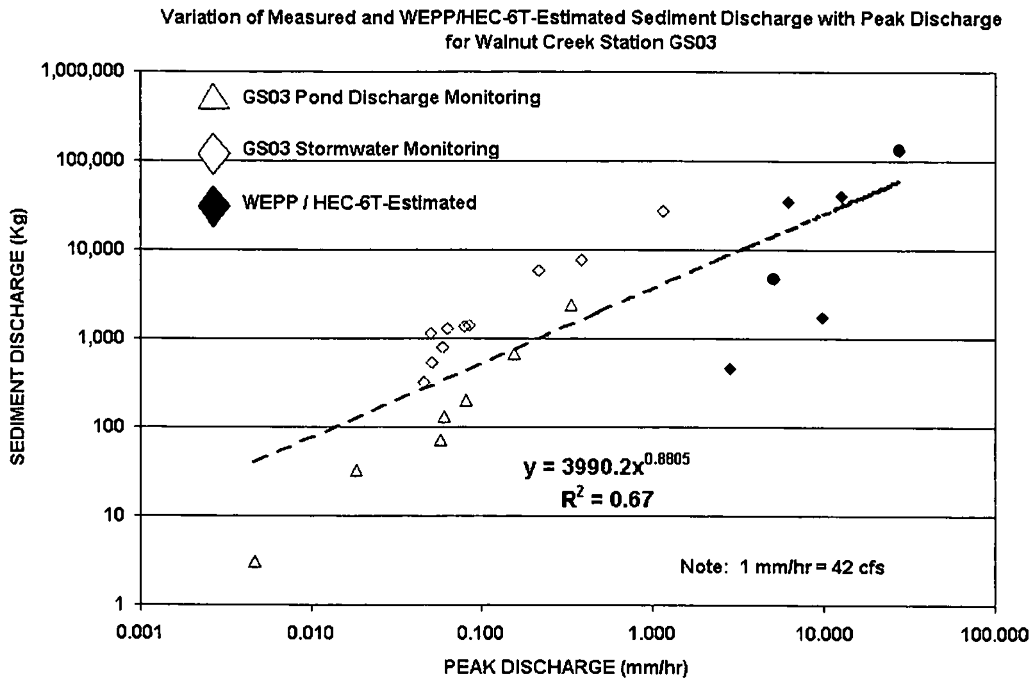
Figure C-12. Comparison of WEPP/HEC-6T Estimated Total Suspended Solids Concentrations with Measured Data





1416

Figure C-13. Comparison of Measured and Simulated Sediment Yields



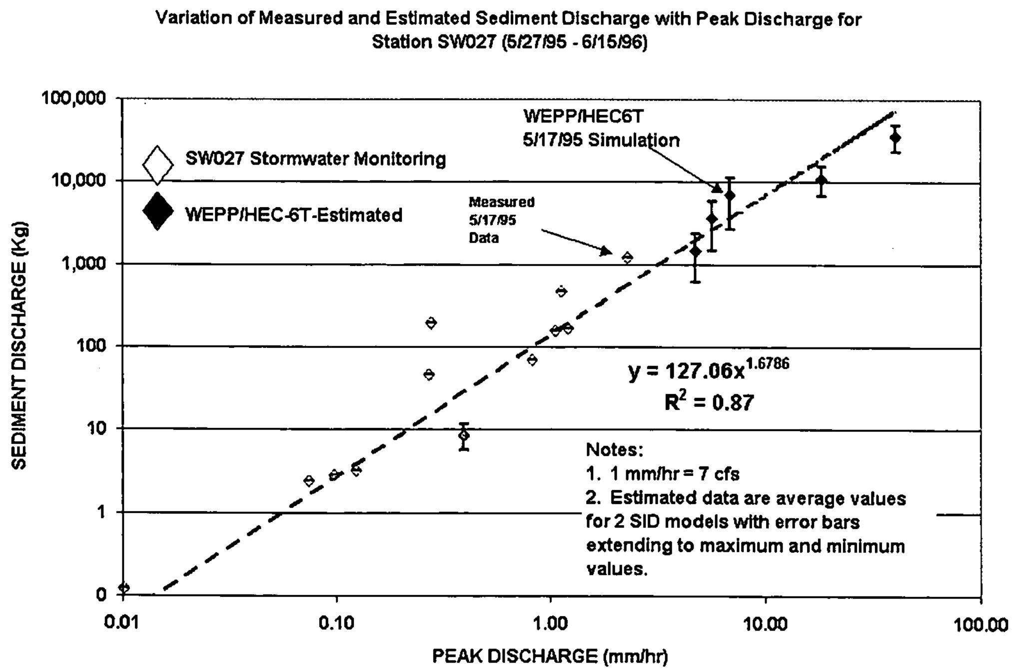
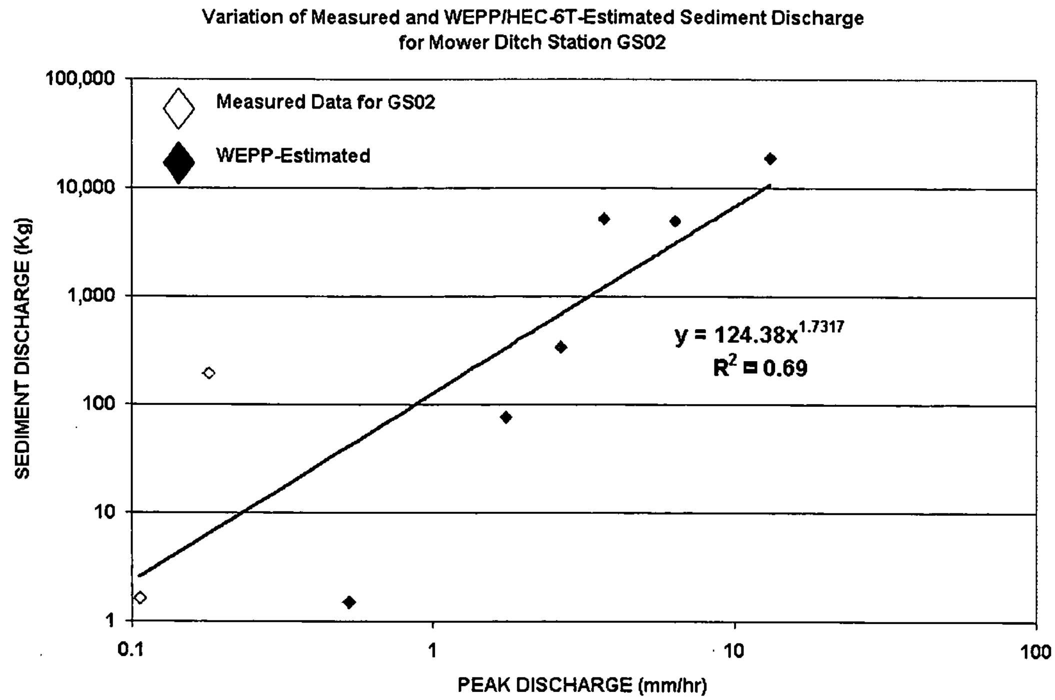
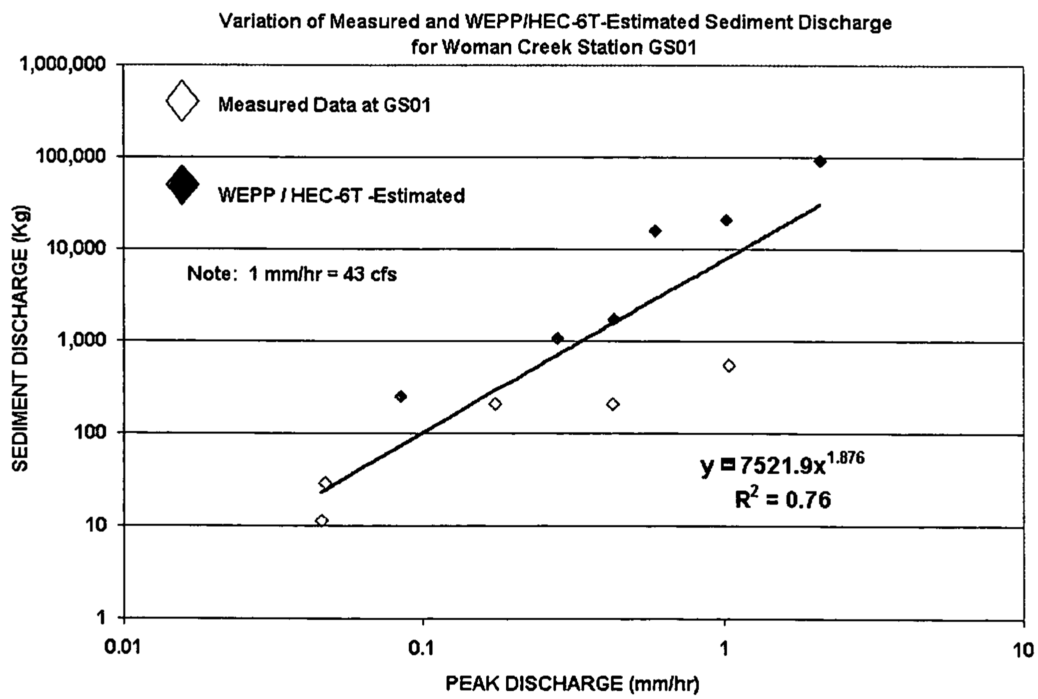


Figure C-14. Comparison of Measured and Simulated Sediment Yields





148

Table D- 6. Data Quality Objectives

ACTINIDE MIGRATION PATHWAYS/PROCESSES	POTENTIAL MODEL NEEDS	LIMITS ON DATA UNCERTAINTY
Diffuse Overland Flow/Soil Erosion	Soil Particle Size and Actinide Association	Percent Colloid, Clay, Silt, Sand, Aggregates/Distribution of Actinides with (MDA = 0.3 pCi/g)
	Soil Isotopic Activity	MDA = 0.3 pCi/g See Attached Limits on Data Uncertainty
	Hill Slopes	2-Foot Contour Interval Resolution
	Channel Geometry	2-Foot Contour Interval Resolution
	Catchment Characteristics	2-Foot Contour Interval Resolution
	Climate/Precipitation	Precipitation =0.01 inches Temperature = 1°C Wind = 1 miles per hour (mph)
	Vegetation (canopy, cover, and type)	OU Investigation Data
	Rill/Inter-Rill Characteristics	Visual Observations/Professional Judgement
	Soil Characteristics	Soil Type, Texture, Bulk Density, Conductivity (high variability)
	Soil Particle Size and Actinide Association	Percent Colloid, Clay, Silt, Sand, Aggregates/Distribution of Actinides (high variability)
	Soil Isotopic Activity	MDA = 0.3 pCi/g See Attached Limits on Data Uncertainty
	Mineral Composition of Surface Soils	Percent Mineral Composition (high variability)
	Soil Organic Content/Characteristics	Percent Organic Content/Type (high variability)
	Surface Water Data for Validation and Verification (See Surface Water Flow)	Discharge: $\pm$5%, TSS: 1 mg/L Activity: 0.03 pCi/L Grain Size Distribution to 2 microns.
	Suspended Solids Grain Size Distribution	Distribution should include size range from 200 microns to 2 microns.
Surface Water Flow/Sediment and Particulate Transport	Surface Water Isotopic Activity	MDA = 0.3 pCi/g. See Attached Limits on Data Uncertainty
	Stream Discharge	0.1 cubic feet per second
	Surface Water and Sediment Isotopic Activity	MDA = 0.3 pCi/g See Attached Limits on Data Uncertainty
	Distribution of Actinides Over Range of Particle Sizes	Distribution should include size range from 2 to 200 microns
	TOC	MDL = 0.1 mg/L
Surface Water Flow/Sediment and Particulate Transport (continued)	Sediment Sources/Sinks	2-Foot Contour Mapping, Visual Observations, Vegetation Mapping
	Total Suspended Solids/Sediment Concentration	Detection Limit = 1 mg/L

APPENDIX C

Range Fire Calibration Summary and Data

150

APPENDIX C TABLE OF CONTENTS

Page

151

Appendix C List of Tables

Page

Appendix C List of Figures

Page

152

C.1 Introduction

The Colorado State University (CSU), Department of Radiological Health Sciences conducted a rainfall simulation study on plots established just to the south of the Rocky Flats Environmental Technology Site (RFETS). The purpose of the study was to quantify runoff, sediment yields, and transport of sorbed nuclides on natural (unburned) and burned plots.

C.2 Calibration of the WEPP Erosion Model to the CSU Burned Plots

The results of the CSU study for natural conditions were used as an aid in the calibration of the RFETS Watershed Erosion Prediction Project (WEPP) Hill Slope Erosion Model for natural conditions, as reported in the *Report on Soil Erosion and Surface Water Sediment Transport Modeling for the Actinide Migration Evaluation at the Rocky Flats Environmental Technology Site* (Kaiser-Hill/RMRS, 2000). The calibration for the natural plots was used as a starting point for the WEPP calibration of the burned plots. The previously calibrated soil parameters were used with the exception of the effective hydraulic conductivity [mm/hr] (Ke). The Ke was reduced for the burn calibration modeling as much as possible for the natural plots, while ensuring that results for runoff and sediment loss was within one standard deviation of the average reported for the rainfall simulator study. The results of the calibration of the WEPP model to the CSU burned plots have been used as the starting point for calibration of the RFETS WEPP Hill Slope Erosion Model for conditions following a range fire.

The soil characteristics and the natural and burned cover data for the rainfall simulator plots are shown in Table C-1. The simulated range fire on the plots was an extreme treatment that destroyed all canopy cover on the burned plots. Bare soil was increased from 29 percent of the surface area to 36 percent, an increase of 29 percent. Persistent litter decreased by approximately 50% while non-persistent litter increased from 3 to 18 percent. Total ground cover was reduced from 71 to 64 percent.

The results of the CSU rainfall simulation study for natural and burned treatments are summarized in Table C-2 and Figures C-1 through C-3. Runoff increased by 34 percent and

153

erosion by 240 percent on the burned "dry" plots compared to the unburned dry plots. The 60-mm rainfall event was applied to dry plots over one hour. The lower rainfall treatments were applied to "wet" and "very wet" plots over a half-hour. Figure C-1 shows that the total sediment loss is greater for the burned plots at all runoff values and that the rate of increase of sediment loss as a function of runoff is greater for the burned plots than for the natural plots. This relationship indicates that the increase in sediment loss on the burned plots is due to an increase in the erodibility of the soil, which may be due to the decrease in foliar and litter cover documented in Table C-1. The soil surface becomes more exposed to direct raindrop impact as foliar cover and litter cover are reduced. The energy released by the raindrops hitting the soil surface breaks up soil aggregates, which leads to decrease infiltration and increase erosion.

Table C-1
Data From the CSU Rainfall Simulator Plots Near RFETS

Characteristics	Units	Observation	
Soil Particle Size Distribution			
Sand	(%)	33.3 (± 5.6)	
Silt	(%)	21.2 (± 4.6)	
Clay	(%)	44.4 (± 6.8)	
Dry bulk density	(g/cm³)	1.30 (± 0.3)	
Organic Matter	(%)	2.6 (± 0.6)	
CEC	(meq/100g)	27.5 (± 2.6)	
Average Slope	(%)	9.1 (± 0.5)	
Random Roughness†	(cm)	1.8	
Canopy Cover		***Natural***	***Burned***
Forbs	(%)	25	0
Grass	(%)	39	0
Shrub	(%)	5	0
None	(%)	27	0
Standing Dead	(%)	4	0
Ground Cover			
Bare soil	(%)	2	36
Gravel	(%)	2	3
Rock (>20 mm)	(%)	1	1
Non-persistent litter	(%)	3	18
Persistent litter	(%)	33	16
Basal Vegetation	(%)	32	26

† Expressed as standard deviation of height measurements

154

The rate of increase for both runoff and sediment loss is greater on the burned plots. Figure C-2 shows the runoff increase on the burned plots relative to the natural plots is less than the increase in sediment loss. The relatively smaller increase in runoff than in erosion on the burned plots indicates that the soil erodibility was increased relative to the natural plots. Figure C-3 shows that the total suspended solids load is about double for the burned plots, but that the rate of increase with increasing precipitation is similar for both natural and burned plots.

Table C-2
Results of the CSU Rainfall Simulation Study, Averages of Three Plots

Treatment	Antecedent Moisture (%)	Rainfall (mm)	Runoff (mm)		Sediment Yield (kg)	
			Natural	Burned	Natural	Burned
Dry (60 min)	12.5 (± 1.4)	60	17.2 (± 2.6)	23.1 (± 4.5)	0.352 (± 0.056)	0.835 (± 0.157)
Wet (30 min)	28.8 (± 2.4)	32	12.8 (± 2.6)	14.8 (± 4.9)	0.181 (± 0.043)	0.421 (± 0.029)
V.Wet (30 min)	35.4 (± 2.8)	32	20 (± 3.75)	19.7 (± 3)	0.210 (± 0.018)	0.497 (± 0.187)
		-------	-------	-------	-------	-------
Totals		124	50	57.6	0.743	1.753

C.2.1 Cover Effects

Canopy cover reduces erosion and sediment losses by intercepting raindrops and reducing their impact energy, which decreases soil detachment and surface sealing. Litter cover shields the soil surface from raindrop impact, affects overland flow hydraulics and reduces sediment detachment and carrying capacity of the flow. Litter, in combination with soil particles and basal vegetation, produces debris dams that encourage ponding, and increase infiltration and sediment deposition. (Lane et al., 1997).

The WEPP model was used to simulate runoff and sediment loss for one-hour rainfall events of 15 mm to 75 mm on hill slopes with the CSU simulator plot dimensions, soil and cover characteristics, and slope. Figure C-4 shows the results using the CSU data in Table C-1. When a Ke of 12.1 is used with the natural plot data the runoff and erosion are very close to the natural plot averages. When the Ke is held constant at 12.1 and the canopy cover and litter cover are set to the post-burn data values for the plots, the runoff is below the burned plot average and sediment losses are nearly an order of magnitude above the burned plot average. When canopy cover is increased to 50% and all other variables are held constant, sediment loss is similar to the burned plot average.

Figure C-5 shows the effect on predicted runoff and sediment loss by varying the canopy cover from 0% to 73% (with litter cover at 64% - the measured litter cover after plots were burned). There is an insignificant reduction in runoff over this range of canopy cover values, while sediment loss decreases dramatically with the increase in canopy cover. Runoff and sediment losses are within one standard deviation of the natural plot average at 73% canopy cover. At 50% canopy cover the runoff does not change significantly but the sediment loss is within one standard deviation of the burned plot average. Thus, in the WEPP model, cover can be used to adjust sediment loss but has a minor effect on runoff values.

C.2.2 Effective Hydraulic Conductivity

The effective hydraulic conductivity (Ke [mm/hr]) is the controlling variable for runoff in the WEPP model (Kaiser-Hill/RMRS, 2000). After a burn, canopy cover and surface ground cover are reduced, exposing more bare soil (Tables C-1 and C-3). The exposed bare soil is subject to more direct raindrop impact and thus increased surface sealing. Under some conditions, fires can make soil somewhat water repellent (hydrophobic) compared to its natural state. The combined effects of the surface sealing and water repellence tend to lower the value of Ke immediately following a fire.

Table C-3
Change in Parameters Measured Before and After Simulated Burn on CSU Plots and Controlled Burn at RFETS [(Post-burn/Pre-burn)*100]

Study	Live Foliar (Canopy) Cover	Total Dead and Live Canopy Cover	Basal Cover	Persistent Litter Cover	Nonpersistent Litter Cover	Total	Biomass Dead	Biomass Live	Rock	Bare Soil
	%	%	%	%	%	%	g/m²	g/m²	%	%
CSU Natural plots	73	ND	32	33	3	72	ND	ND	3	28
CSU Burn Plots	0	ND	26	16	18	64	ND	ND	4	36
Change (%/100)	1	-0.11	-0.19	-0.52	6.0	-0.11	ND	ND	1.33	1.29
RFETS Natural	99	99	ND	ND	ND	81	277	189	10	2
RFETS Controlled Burn	5	94	ND	ND	ND	73	108	17	.13	6
Change (%/100)	-0.95	-0.05	ND	ND	ND	-0.90	-0.61	-0.91	1.3	3.0

WEPP simulated runoff values for the rainfall simulator plots for a range of Ke, canopy cover, and litter cover values are shown in Figure C-6. Canopy and litter covers have no significant effect on runoff, as shown by the tightly grouped points at each Ke value. A Ke value of 9.4 yields an estimated runoff value equal to the average for the burned plots. Figure C-7 shows that litter cover controls sediment loss at low canopy cover values. Ke has a small effect at low canopy cover values. The effect of both variables becomes smaller as canopy cover increases.

The evaluation indicates that the Ke values on the hill slopes must be reduced to simulate the higher runoff rate after a burn. The increased runoff rate after a fire is likely due to the combined effects of increased water repellence and soil sealing due to increased raindrop impact, which tend to lower the value of Ke.

C.2.3 Interrill (Ki) and Rill (Kr) Erodibility

Interrill and rill erodibility are important variables controlling sediment loss in the WEPP model. The Ki is most important on short hill slopes, as the hill slope length increases the Kr value becomes more important. It is a difficult task to calibrate these values on a short hill slope and transfer the results to longer hill slopes, as discussed in the AME report on soil erosion (Kaiser-

Hill/RMRS, 2000). The WEPP model also adjusts the Ki using the input cover parameters. Figure C-8 shows the effect of varying Ki at three values of Ke when canopy cover and litter cover are set to the values reported for the burned plots and rainfall is 60 mm per hour. Sediment loss increases with increasing Ki and is most affected by Ke at high Ki values. The Ki must be reduced from 9.84E-08, the value used to calibrate the natural plots, to less than 1E+07 to simulate the burned plot erosion data.

Figure C-9 shows that the rill erodibility variable has no effect on sediment loss on the plots over the range of Kr values used. This is due to the short slope length of the plots. Kr becomes more important on longer slope lengths (Kaiser-Hill/RMRS, 2000).

C.2.4 Interaction of Canopy Cover and Ki

Figure C-10 shows the affect on sediment loss when the canopy cover and Ki parameters in WEPP are varied together. The average sediment loss for the burned plots is 0.848 +/- 0.173 kg. The combinations of canopy cover and Ki values that yield sediment loss values within one standard deviation of the average for the burned plots are possible choices for calibration of the WEPP model to the simulator plot results (Figure C-11). However, it may not be advantageous to vary the Ki parameter for soils in the RFETS WEPP Hill Slope Erosion Model. Previously reported results for WEPP model parameter sensitivity and calibration to the RFETS hill slopes (Kaiser-Hill/RMRS, 2000) indicated that both Ki and Kr interact with hill slope length. Therefore increasing the Ki or Kr based on the results for the short simulator plots may lead to undesirable overestimates of sediment loss on longer hill slopes.

The interaction of the erodibility parameters, Ki and Kr, with both cover and slope length in the WEPP model make their use in calibrating the model to post-burn conditions less desirable than other alternatives.

C.3 Discussion and Application to the SID Simulated Burn

The WEPP model was calibrated to the CSU natural simulator plots, using observed soil and cover data. When cover data for the burned CSU plots are used as input to the WEPP model and the Ke and Ki parameters are held at the values used for the calibration of the natural plots, the WEPP model under-predicts runoff and over-predicts sediment loss. The results of varying Ke, Ki, and canopy cover are summarized below:

1. The burned plot average runoff value of 23.1 mm can only be simulated by lowering the Ke to about 9.4 (Figure C-6)

2. The burned plot average runoff and sediment loss can be simulated by lowering the Ke to 9.4, holding the Ki parameter at the 9.84e+06 value used for calibration of the natural plots, using the observed post-burn litter cover (64%), and adjusting canopy cover to about 50% (Figure C-7).

3. Lowering the Ke to 9.4 and the Ki to between 9.84e+06 and 5.84e+06 simulates the burned plot average runoff and sediment loss when canopy cover is at 0% and litter cover is at 64% (Figure C-8).

4. The burned plot average runoff and sediment loss can be simulated by simultaneously lowering the Ki and the canopy cover parameters. Combinations of input values that estimate the burned plot average sediment loss plus or minus one standard deviation are shown in Figure C-10.

The analysis presented in steps 1 to 4 above indicates that a combination of adjustments in the Ke, cover and the Ki parameters must be used to simulate increases in runoff and erosion due to a range fire. Several combinations of canopy cover and Ki are shown in Figure C-11.

Data collected by the RFETS Ecology Group before and after a controlled burn in the southwestern sector of the Site show that the burn treatment used on the simulator plots was much more extreme than the controlled burn (Table C-3). The CSU runoff and sediment loss data for the simulator plots provide upper-bound estimates for the burn simulation on the SID hill slopes. Comparison of the CSU data to the RFETS controlled burn data indicate that the WEPP calibration parameters need to predict results that represent a balance between the CSU data and the RFETS controlled burn data. The following protocol was used to achieve balance in the

129

range-fire calibration. Values used to calibrate WEPP for the burned SID watershed hill slopes are presented in Table C-4.

Calibration Protocol

1. The Ki value was held constant to avoid problems arising from an interaction between Ki and hill slope length.
2. The Ke values were adjusted to produce an average increase in runoff of 24% as measured for the CSU burned plots.
3. The canopy and litter values were adjusted using data from the CSU plots and the RFETS controlled burn.
4. Refinements were made to the calibration using a target average increase in sediment loss of approximately 70%, which is about half of the upper bound for the CSU simulator study.

1160

Table C-4

Summary of WEPP Parameters Used to Simulate Runoff and Erosion for Natural and Burned Conditions on Plots and SID Hill Slopes. All parameters are the Same as Natural Conditions Except Cover Parameters and Ke as Adjusted.

Condition	Effective Hydraulic Conductivity - Ke (mm/h)	Interrill Erodibility Ki	% Canopy Cover	% Interrill Litter + Basal Cover	% Rill Litter + Basal Cover	Comments
CSU Natural Plots	12.1	9.84e+08	73	72	72	Ke and Ki estimated during calibration; cover data from plots; interrill and rill cover were not differentiated.
CSU Burn Plots	9.4	9.84e+08	50	64	64	Ke calibrated to post-burn runoff; canopy cover calibrated to post burn sediment loss
Change (%/100)	0.32	0	0.32	0.11	0.11	
SID Simulated Natural	8.5 – 1.0	9.84e+08	0.85, 0.78, 0.85	1.14, 0.97, 0.81	0.58, 0.63, 0.55	Ke varied by OFE to calibrate runoff to SID flow; cover parameters are for Mesic, Regrass and Agrass vegetation types.
SID Simulated Burn	6 – 0.4	9.84e+08	0.80, 0.73, 0.80	0.96, 0.82, 0.70	0.50, 0.54, 0.49	Ke calibrated to increase runoff by an average of 24%; change in cover based on controlled burn data and calibrated to increase sediment loss by an average of 70%.
Change (%/100)	0.29-0.6	0	0.06	0.14 – 0.16	0.11 – 0.15	

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APPENDIX C FIGURES

Figure C-1. Total Sediment Loss a Function of Runoff for Simulator Plots; Each Point is the Average of Three Plots

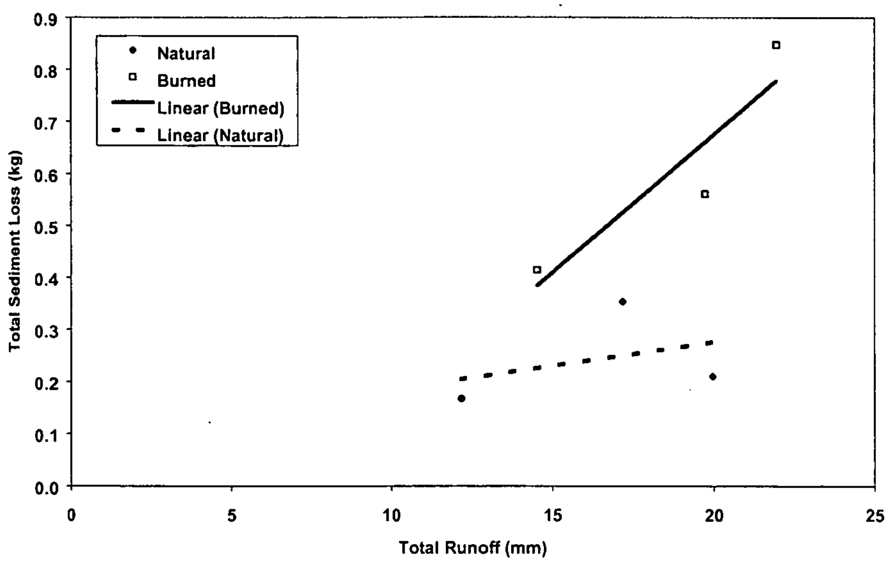
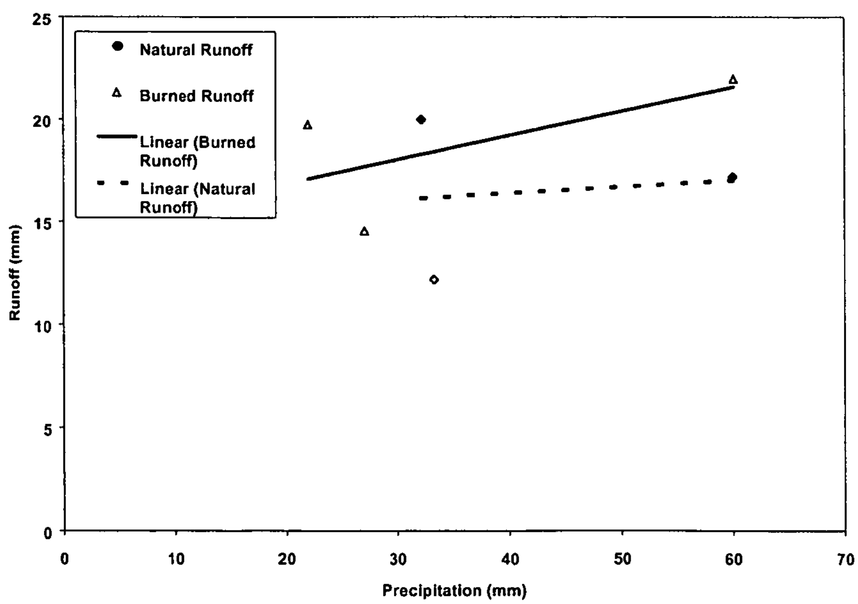


Figure C-2. Runoff and Sediment Loss as Functions of Precipitation, Each Point is the Average of Three Plots



163

Figure C-3. Total Suspended Solids in Runoff as a Function of Precipitation for Natural and Burned Plots; Each Point is the Average of Three Plots

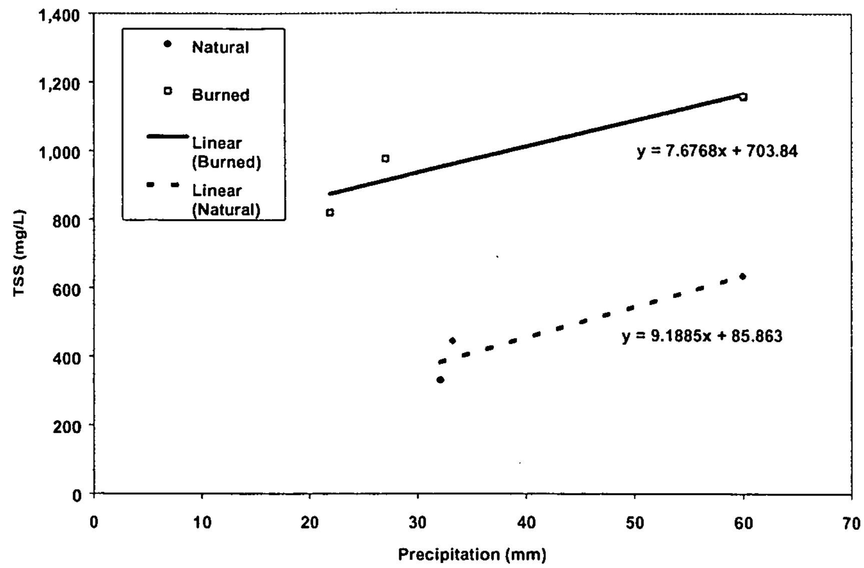
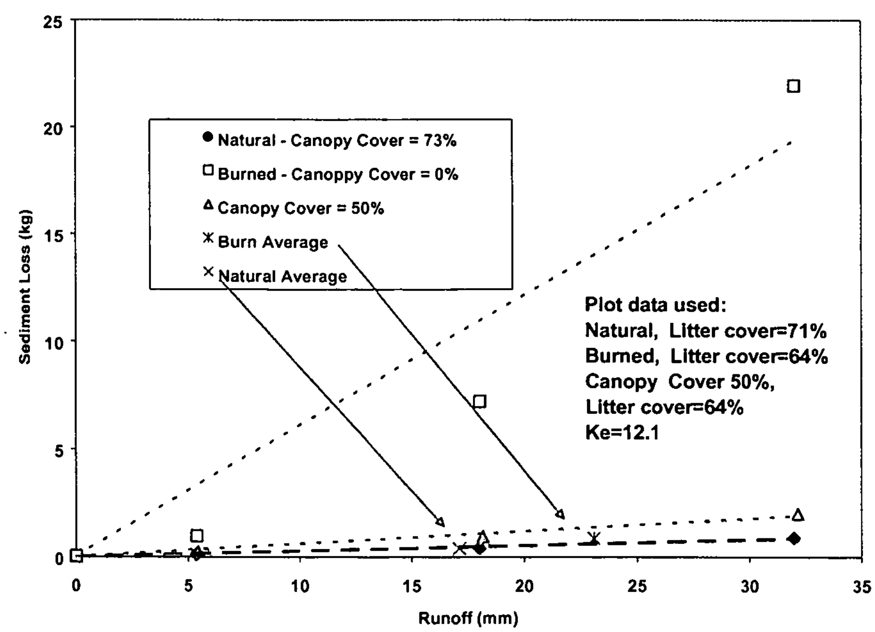


Figure C-4. Sediment Loss Versus Runoff Modeled on Simulator Plots Using WEPP and Precipitation Events From 15 mm to 75 mm and a One-hour Duration



164

Figure C-5. Modeled Runoff and Sediment Loss From Simulator Plot for 60-mm Event With Biomass Reduced by %, Litter Cover at Values Measured After Burning Plot and Canopy Cover Set to a Range of Values

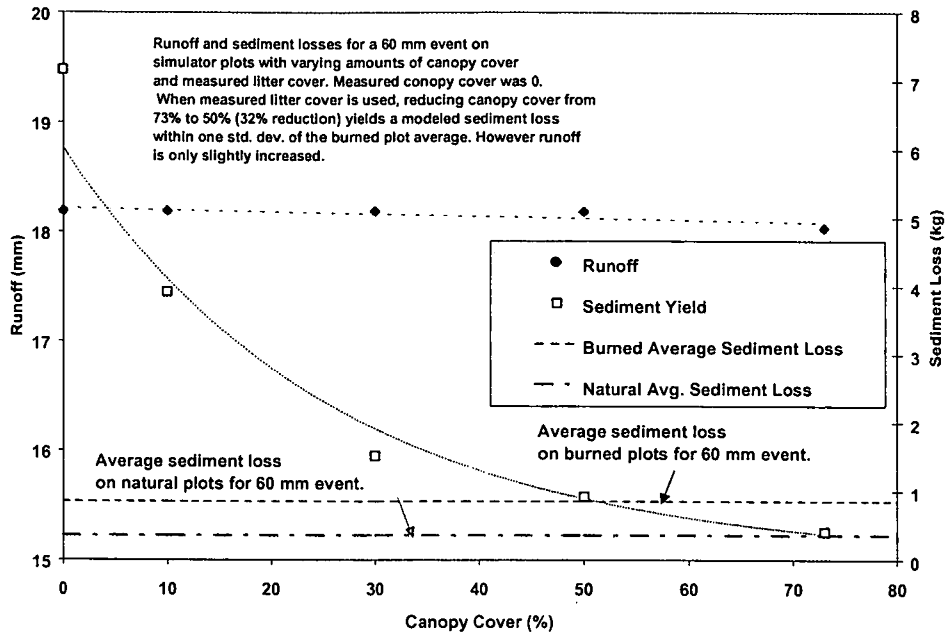
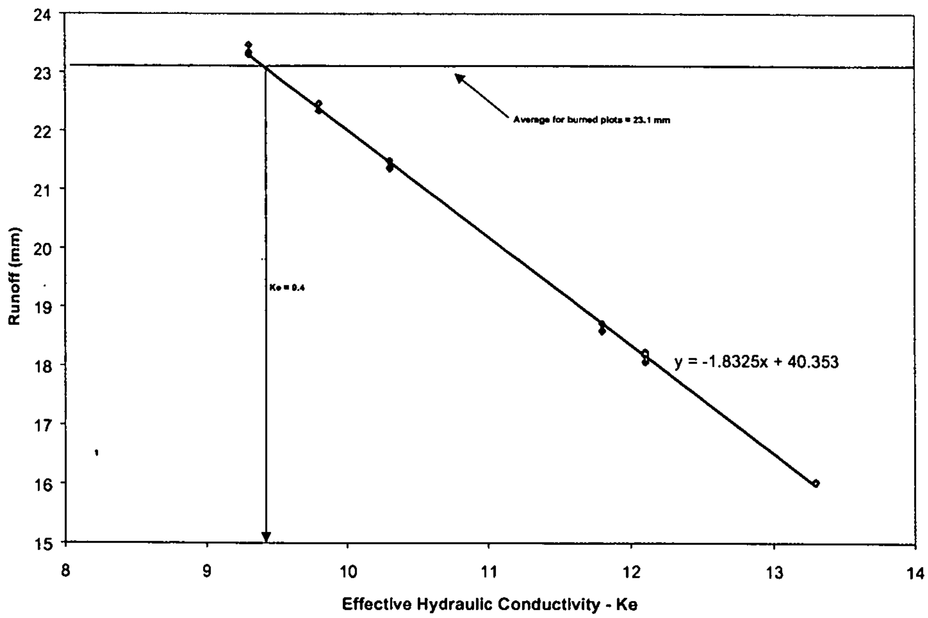


Figure C-6. Effect of Changes in Ke and Litter Cover Values on Simulated Runoff From Plots



163

Figure C-7. Effect of Ke and Litter Cover Values on WEPP Simulated Sediment Loss From Plots

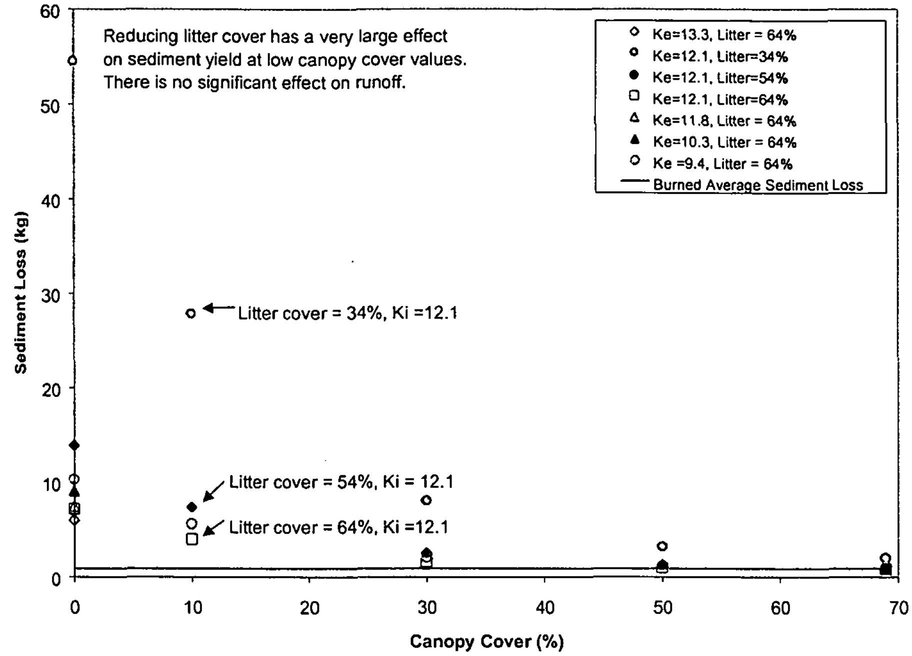


Figure C-8. Effect of Ke and Ki on WEPP Simulated Sediment Loss From Plots

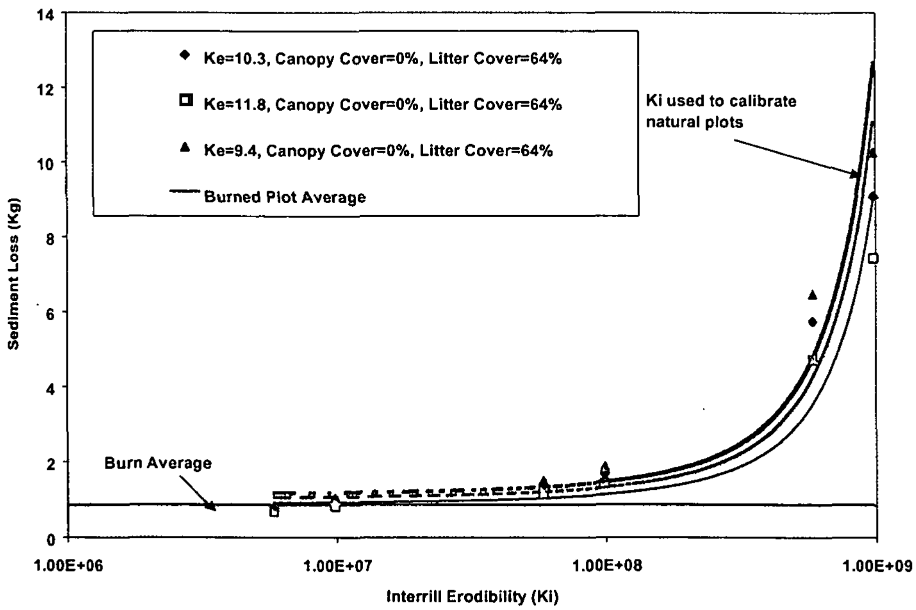


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Figure C-9. Effect of Kr Values on WEPP Simulated Sediment Loss From Plots at Two Values of Ki

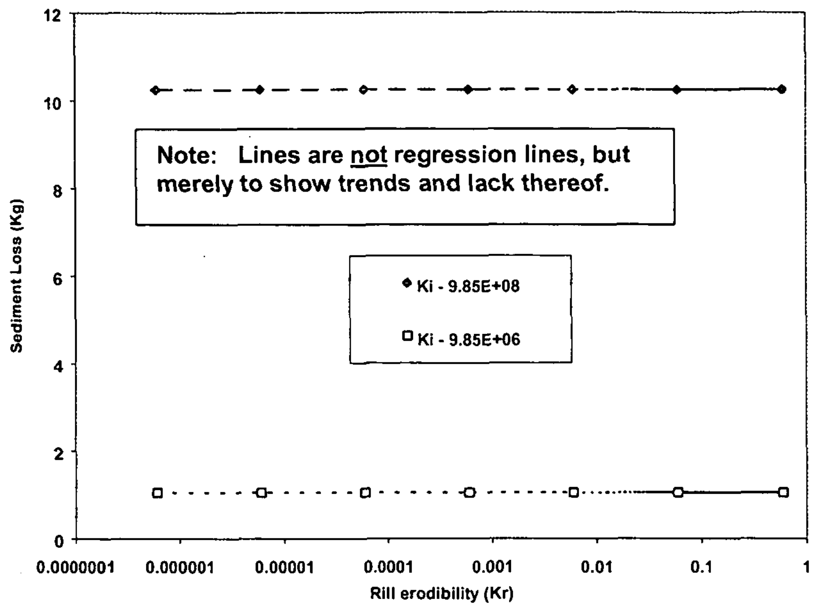
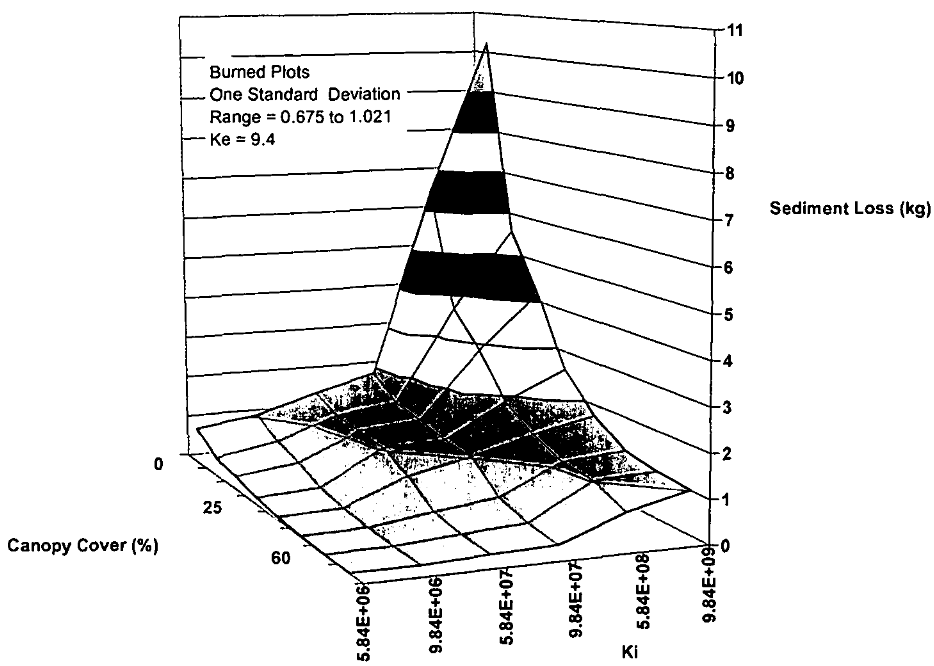
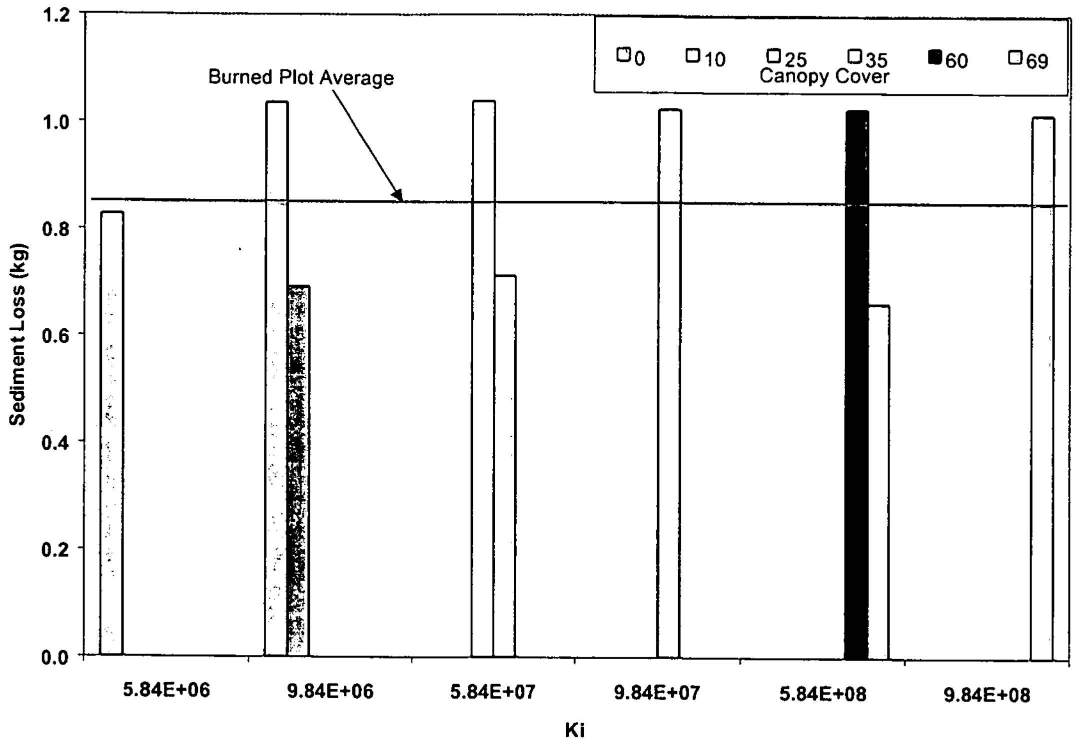


Figure C-10. Modeled Sediment Loss at a Ke of 9.4 and a Range of Canopy Cover and Ki Values



167

Figure C-11. Combinations of Canopy Cover and Ki That Predict Sediment Loss From Plots to be Near the Average Plus or Minus One Standard Deviation



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168

APPENDIX D

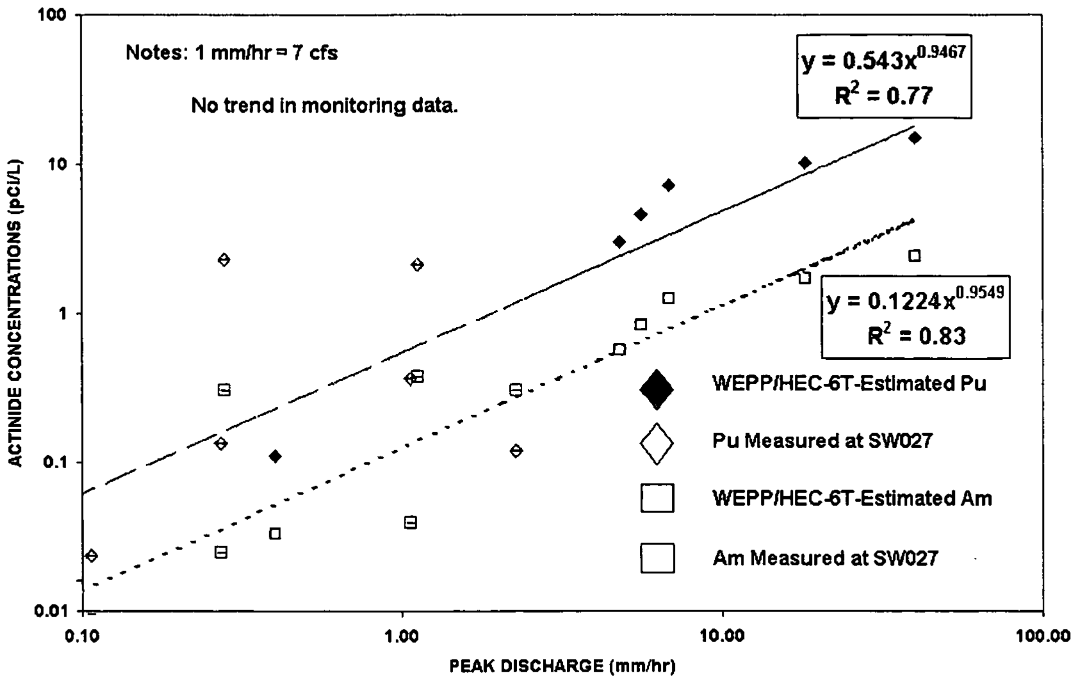
Supplemental Erosion and Actinide Mobility Maps

169

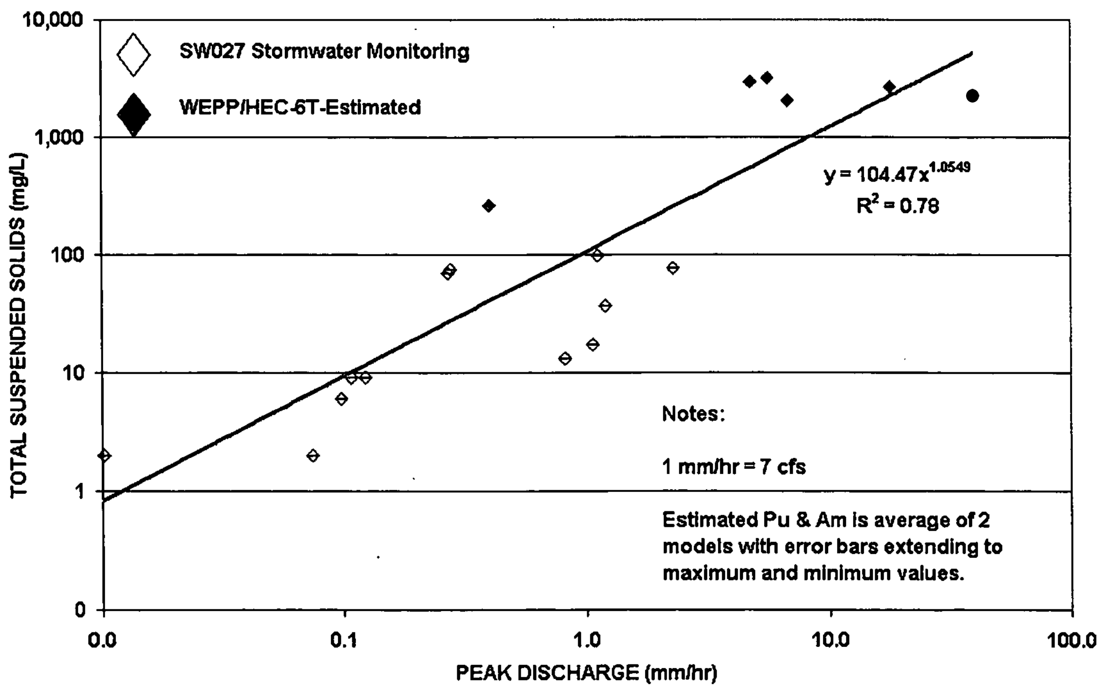
This appendix contains supplemental erosion, isoplot, actinide mobility maps, and updated plots comparing model results to monitoring data. The erosion maps for the design storms for the SID watershed are corrected versions of the erosion maps published in the 2000 report. The isoplots are the edited Kriged grids to account for the samples collected on the 903 pad and lip area roads.

170

Comparison of Simulated and Measured Actinide Concentrations for the SID at SW027

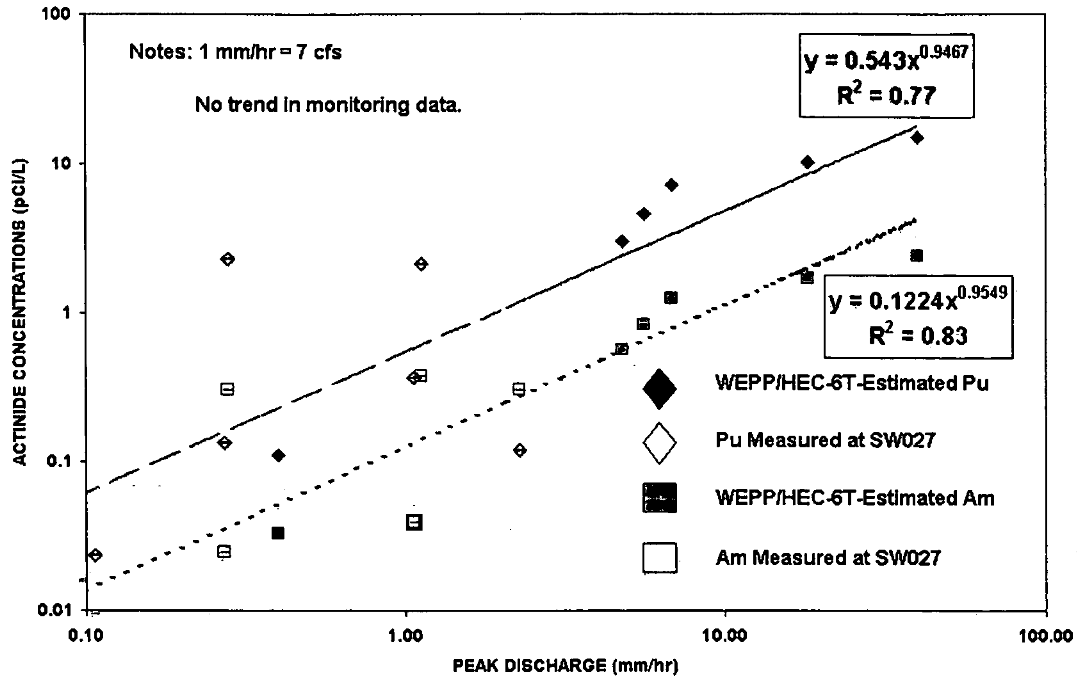


Variation of Measured and WEPP/HEC-6T-Estimated Total Suspended Solids Concentration with Peak Discharge for SID Station SW027

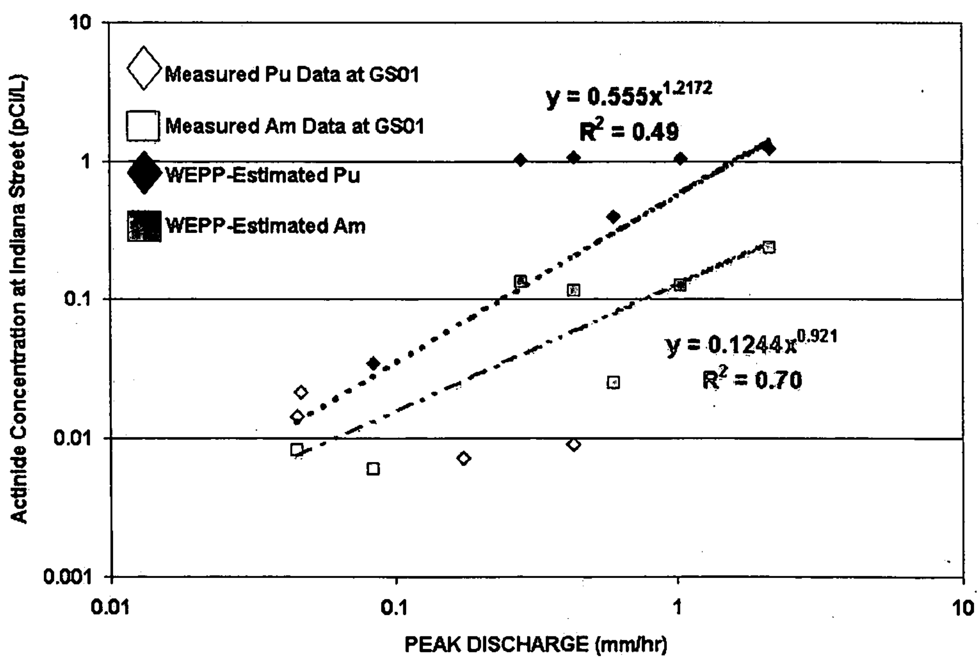


181

Comparison of Simulated and Measured Actinide Concentrations for the SID at SW027

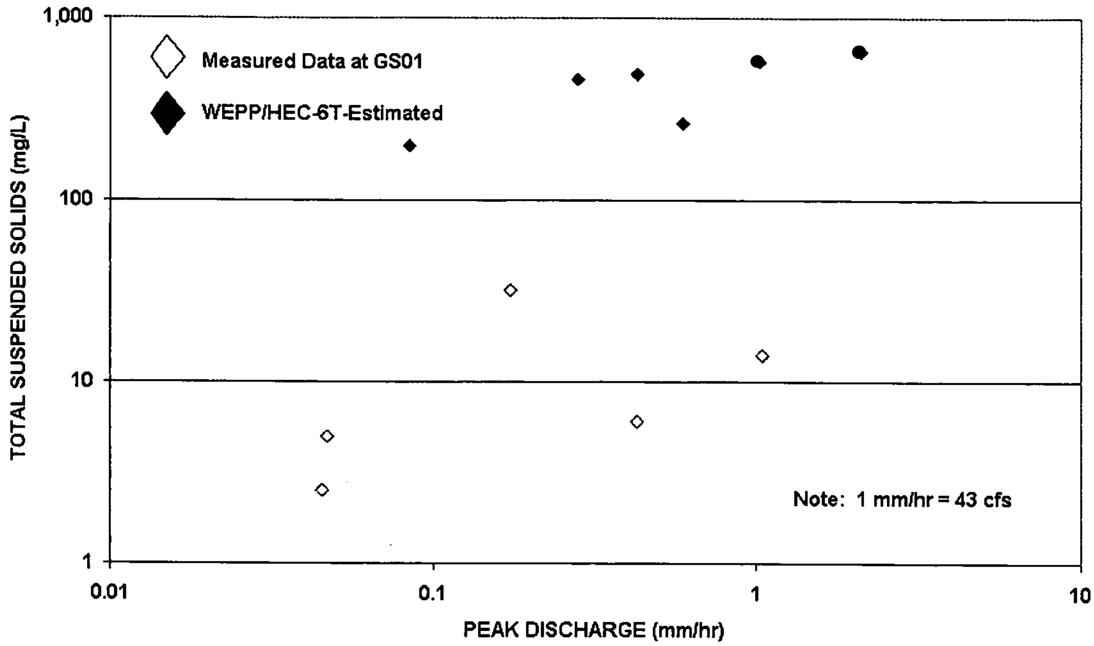


Variation of Measured and Estimated Average Actinide Concentration
with Peak Discharge for Woman Creek at GS01

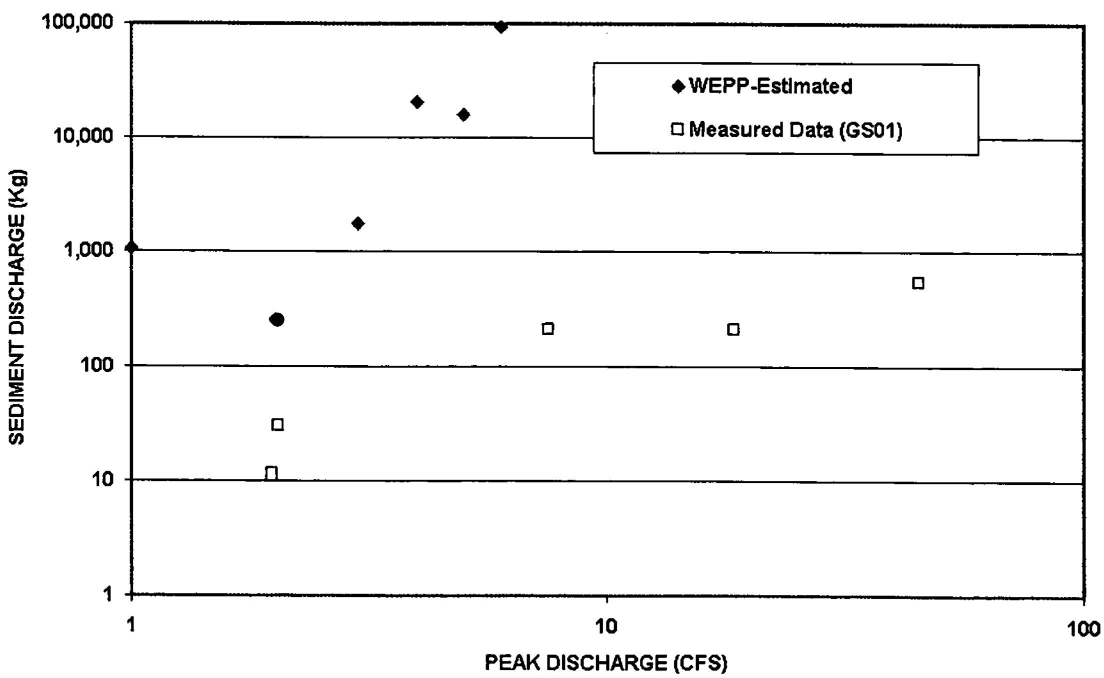


182

Variation of Measured and WEPP-Estimated Total Suspended Solids Concentration with Peak Discharge for Woman Creek

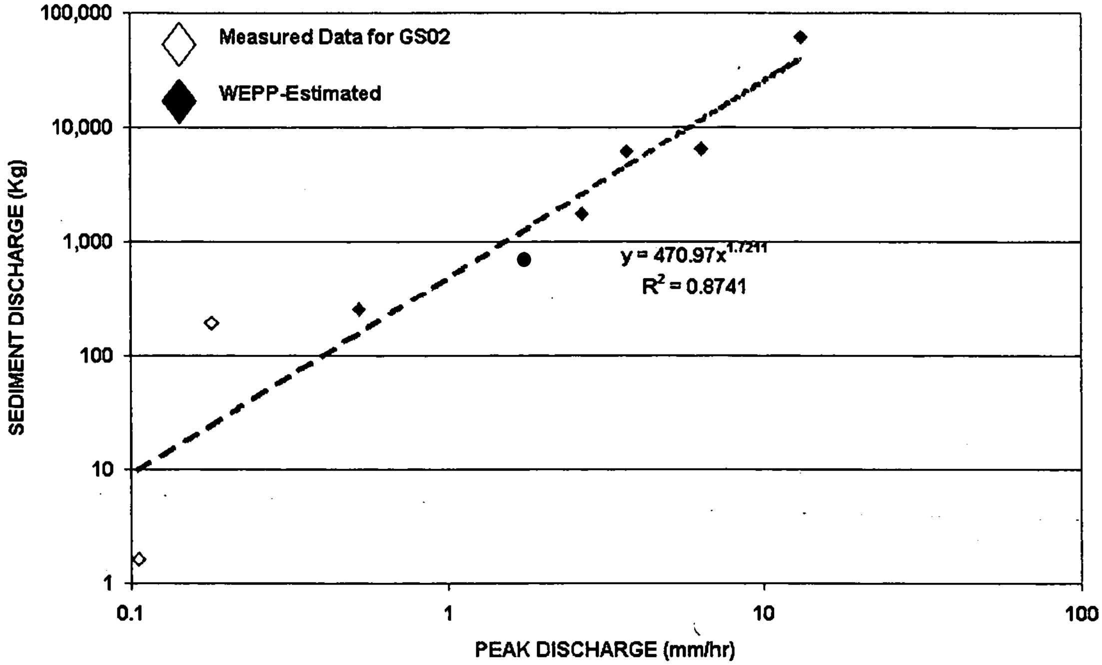


WEPP-Estimated Sediment Discharge Curve for Woman Creek

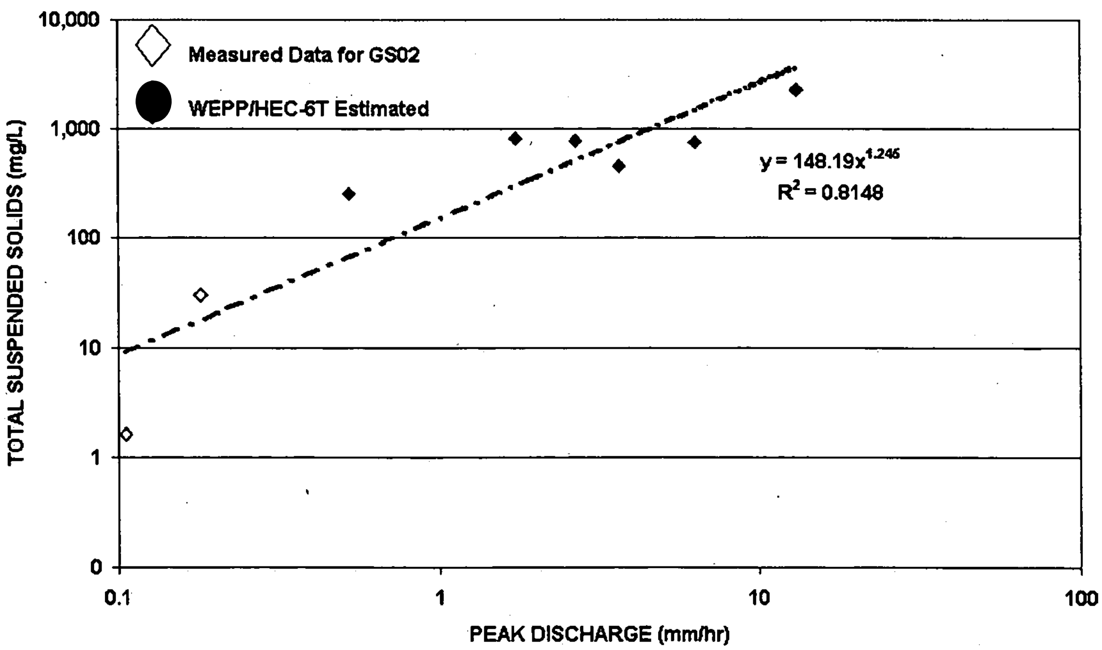


183

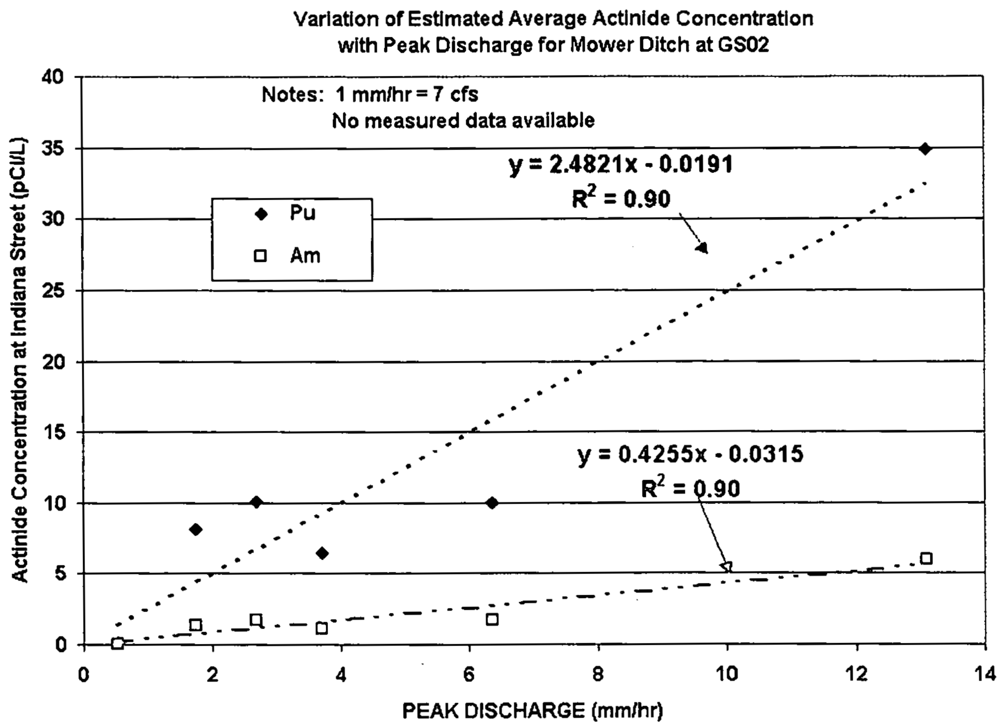
Variation of Measured and WEPP/HEC-6T-Estimated Sediment Discharge for Mower Ditch Station GS02



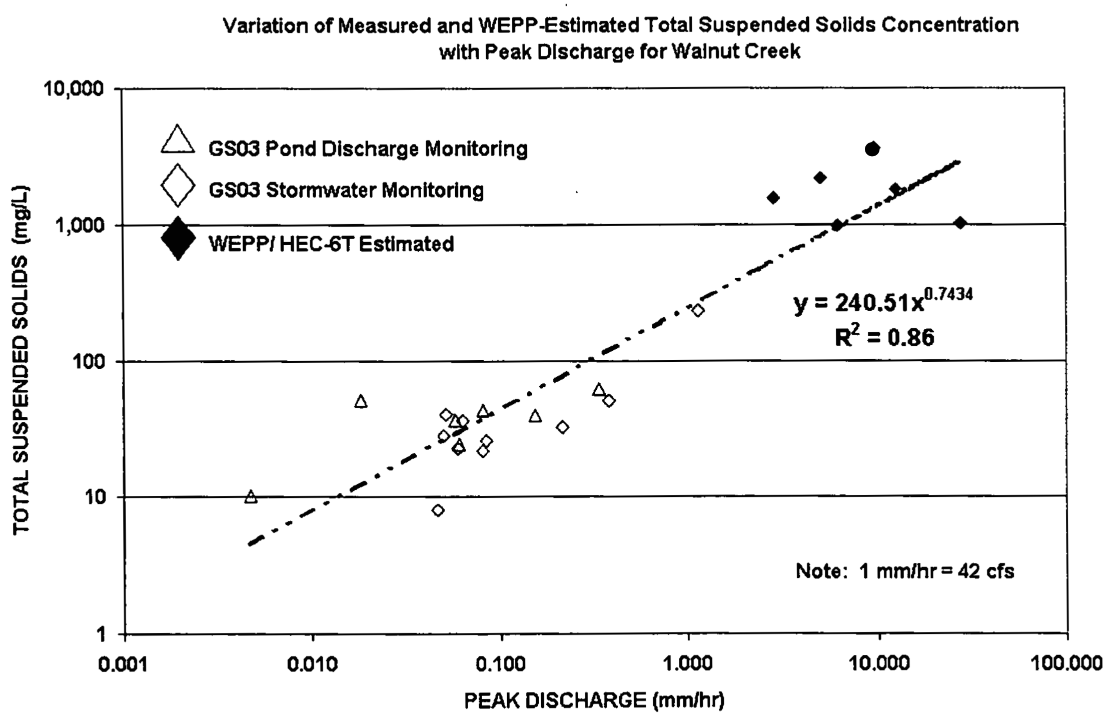
Variation of Measured and WEPP-Estimated Total Suspended Solids Concentration with Peak Discharge for Mower Ditch



184



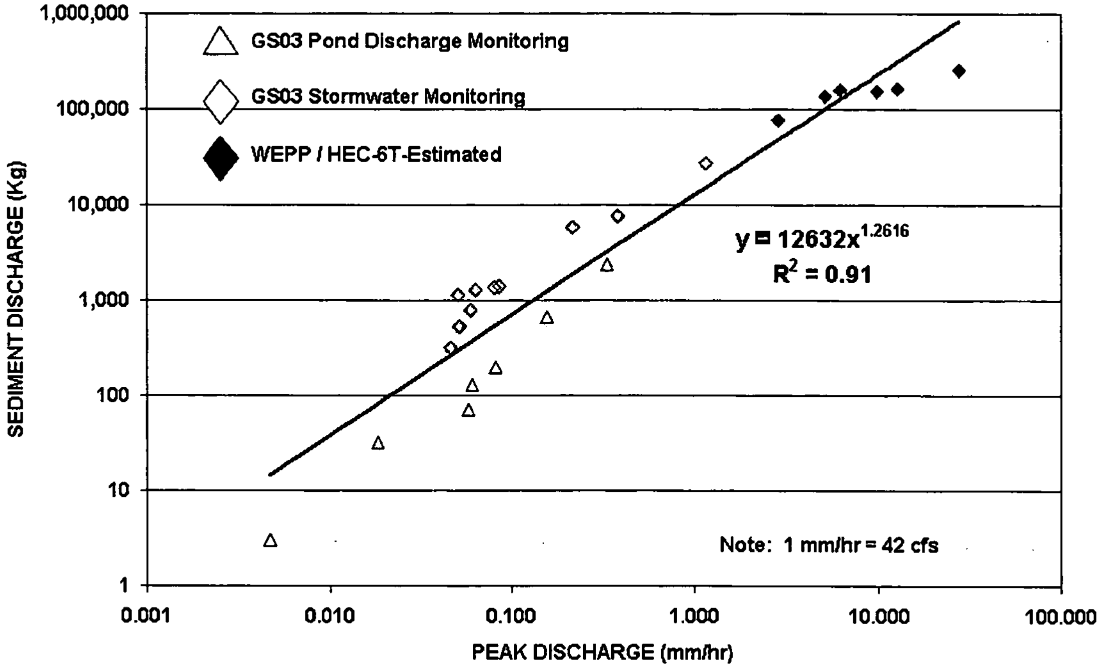
Variation of Estimated Average Actinide Concentration
with Peak Discharge for Mower Ditch at GS02
Notes: 1 mm/hr = 7 cfs
No measured data available
Pu
Am
y = 2.4821x - 0.0191
R2 = 0.90
y = 0.4255x - 0.0315
R2 = 0.90
Actinide Concentration at Indiana Street (pCi/L)
PEAK DISCHARGE (mm/hr)



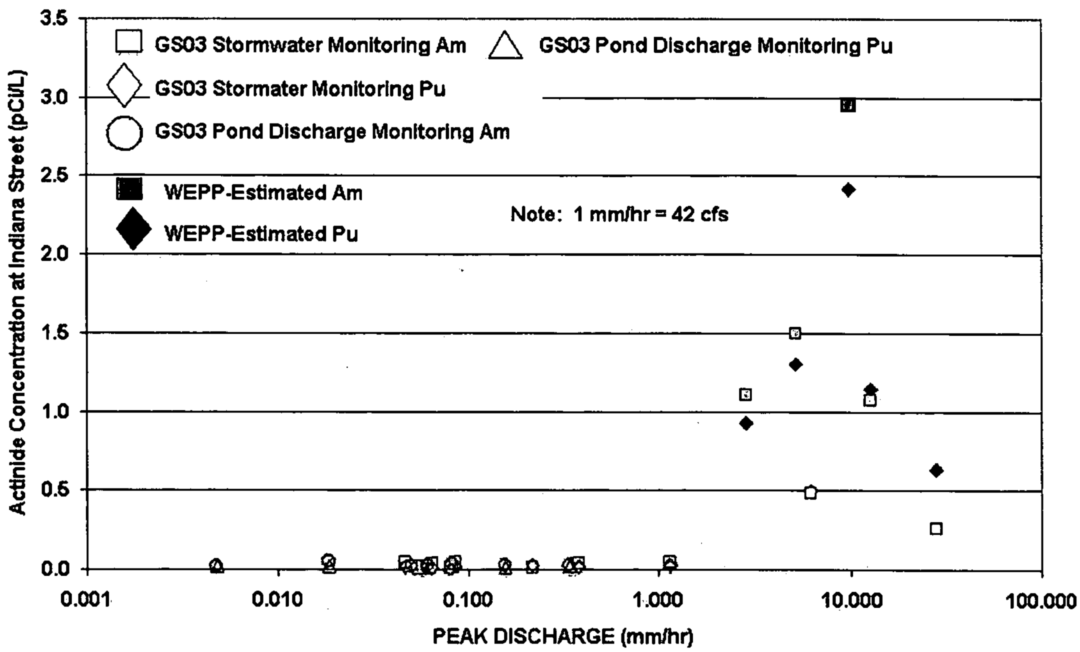
Variation of Measured and WEPP-Estimated Total Suspended Solids Concentration
with Peak Discharge for Walnut Creek
GS03 Pond Discharge Monitoring
GS03 Stormwater Monitoring
WEPP/ HEC-6T Estimated
y = 240.51x0.7434
R2 = 0.86
Note: 1 mm/hr = 42 cfs
TOTAL SUSPENDED SOLIDS (mg/L)
PEAK DISCHARGE (mm/hr)

185

Variation of Measured and WEPP/HEC-6T-Estimated Sediment Discharge with Peak Discharge for Walnut Creek Station GS03



Variation of Measured and Estimated Average Actinide Concentration with Peak Discharge for Walnut Creek



186

APPENDIX E

HEC-6T Model Calibration

APPENDIX E
HEC-6T MODEL CALIBRATION

The fiscal year 2000 HEC-6T models were recalibrated for Woman Creek, Walnut Creek, the South Interceptor Ditch (SID) and Mower Ditch based on techniques provided by the model developer, Tony Thomas. This appendix demonstrates model calibration methodologies and results for HEC-6T.

1.0 CALIBRATION METHODOLOGY

Model calibration was accomplished by matching the active sediment layer bed gradation curves for the incoming base flow with the streambed gradation measured in the field. Cross-sections with little change in erodible depth and constant velocities from upstream to downstream should be selected for model calibration. HEC-6T models are calibrated by altering three primary parameters including: (1) base flow time step, (2) base flow discrete flows and (3) particle size distribution for base flow inflows. Altering these parameters has the net effect of armoring the channel bed and decreasing overall bed sediment mass loads exiting each model segment. All size distributions (clay to large boulders) must be represented in the HEC-6T model prior to beginning the model calibration steps.

1. Addition of Base Flow Time Steps. Base flow time steps are added prior to the hydrograph time steps from the model, as demonstrated in the SID watershed HEC-6T input file (Figure E-1).

188

Figure E-1. SID Watershed HEC-6T Base Flow Input (.T5) File

```
1234567890123456789012345678901234567890123456789012345678901234567890123456789
$HYD
$RATING 1
RC           40         30          0          0          0        .72        1.0       1.23       1.42
RC         1.59       1.74       1.89       2.03       2.16       2.29       2.42       2.54       2.66
RC         2.78       2.90       3.01       3.13       3.24       3.36       3.48       3.60       3.72
RC         3.85       3.98       4.11       4.26       4.42       4.60       6.28       6.82       7.39
RC         7.97       8.57       9.19       9.83      10.49      11.16      12.57      13.30
*         SID, P = 97.1, HP = 1/6, BASEFLOW
Q 0.0000  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
Q 0.0000  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0500
R 5777.3
T 50.000  50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000
T 50.000  50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000    50.000
W        1
*   ABC   SID, P = 97.1, HP = 1/6, BASEFLOW
Q 0.0000  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
Q 0.0000  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0500
W        1
*         SID, P = 97.1, HP = 1/6, ORIGINAL
Q 0.1977  0.9809    2.0961    0.5870    1.8409    0.1137    5.1533    4.3452    4.5623    4.2870
Q 0.5544  0.1358    0.2117    1.5217    2.2486    1.5774    0.1054    0.2076    4.8225    0.1000
W 0.0014
```

Column Ruler

Plot Statement For Bed Gradation

Time-Steps (days)

Baseflow (cfs)

Highlighted areas show base flow values (yellow) and daily base flow time steps (green). Base flow is simulated by changing all inflow values, except segments containing base flow, to zero. The number of base flow time steps is adjusted until the closest fit is obtained between the field-measured and predicted bed gradation curves. Bed gradation curve data are output to the .T6 file by adding the C to the sixth column of the * line of the HEC-6T input file (.T5) for the final base flow time step, which is highlighted in red in the above SID input file section.

2. Changing Base Flow. Base flow, in units of cubic feet per second, is added for each segment of the model that contains base flow. Example base flow values are shown in yellow in Figure E-1. The base flow values for each segment are changed until a match is achieved between the predicted and measured gradations.

3. Alteration of Inflow Sediment Particle Size Distributions. If steps one and two have not led to an adequate model calibration, the final option is to alter the inflow particle size distribution (PSD) for the base flow segments. An example of base flow PSDs for the SID model HEC-6T .T5 input file is shown in Figure E-2.

189

Figure E-2. SID HEC-6T Base Flow Particle Size Distribution .T5 Input File

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890

LQ Q_CFS    .0001    1.50    12.1    21.8    28.6      50
LCQS_PPM        0       0   105.1   114.8   151.2   310.3
LF  CLAY     .069    .069    .069    .069    .069    .069
LF SILT1        0       0       0       0       0       0
LF SILT2     .038    .038    .038    .038    .038    .038
LF SILT3     .239    .239    .239    .239    .239    .239
LF SILT4        0       0       0       0       0       0
LF 1-VFS     .099    .099    .099    .099    .099    .099
LF  2-FS        0       0       0       0       0       0
LF  3-MS     .555    .555    .555    .555    .555    .555
LF  4-CS        0       0       0       0       0       0
LF 5-VCS    0.000   0.000   0.000   0.000   0.000   0.000
LF 6-VFG    0.000   0.000   0.000   0.000   0.000   0.000
LF  7-FG    0.000   0.000   0.000   0.000   0.000   0.000
LF  8-MG    0.000   0.000   0.000   0.000   0.000   0.000
LF  9-CG    0.000   0.000   0.000   0.000   0.000   0.000
LF10-VCG    0.000   0.000   0.000   0.000   0.000   0.000
LF 11-SC    0.000   0.000   0.000   0.000   0.000   0.000
LF 12-LC    0.000   0.000   0.000   0.000   0.000   0.000
LF 13-SB    0.000   0.000   0.000   0.000   0.000   0.000
LF 14-MB    0.000   0.000   0.000   0.000   0.000   0.000
PF   SID     7627       0     610     305       0       0
PF   SID     7417     .01      70      32      90     0.1      82    0.06      80
PFC0.025       78   0.005      25  0.0023      15
PF   SID     7368       0     610     305       0
```

Column Ruler

Coarse Particle Sizes Added to Model

Percent Finer Bed Sediment Gradation Curve (See Fig E-3)

Percent Finer Curve for Riprap Drop Structures

Particle size distribution values are shown in yellow in Figure E-2. These values are adjusted until model calibration is achieved.

2.0 MODEL CALIBRATION RESULTS

Results of the model calibration runs are shown in Figures E-2 through E-5. The figures show predicted versus actual field-measured bed gradations for Walnut Creek, Woman Creek, the SID and Mower Ditch. As can be seen, a reasonable curve fit was achieved for all modeled locations except for Walnut Creek. Model calibration results are discussed below.

2.1 Mower Ditch, Woman Creek and the South Interceptor Ditch

Model calibration was adequately achieved for Mower Ditch, Woman Creek and the SID by changing base flow time steps and flows as demonstrated in Figures E-3 through E-5. The

190

number of base flow time steps and the amount of base flow required to calibrate Mower Ditch, Woman Creek and the SID are all shown in Table E-1.

Table E-1

Mower Ditch, Woman Creek and SID Model Calibration Base Flow Time Steps and Flows

WATERSHED NAME	NUMBER OF MODEL SEGMENTS WITH BASE FLOW	BASE FLOW DURATION/TIME STEPS (Days)	BASE FLOWS (CFS)
Mower Ditch	1	2	0.01
Woman Creek	3	8	0.07, 0.05, 0.05
SID	1	2	0.05

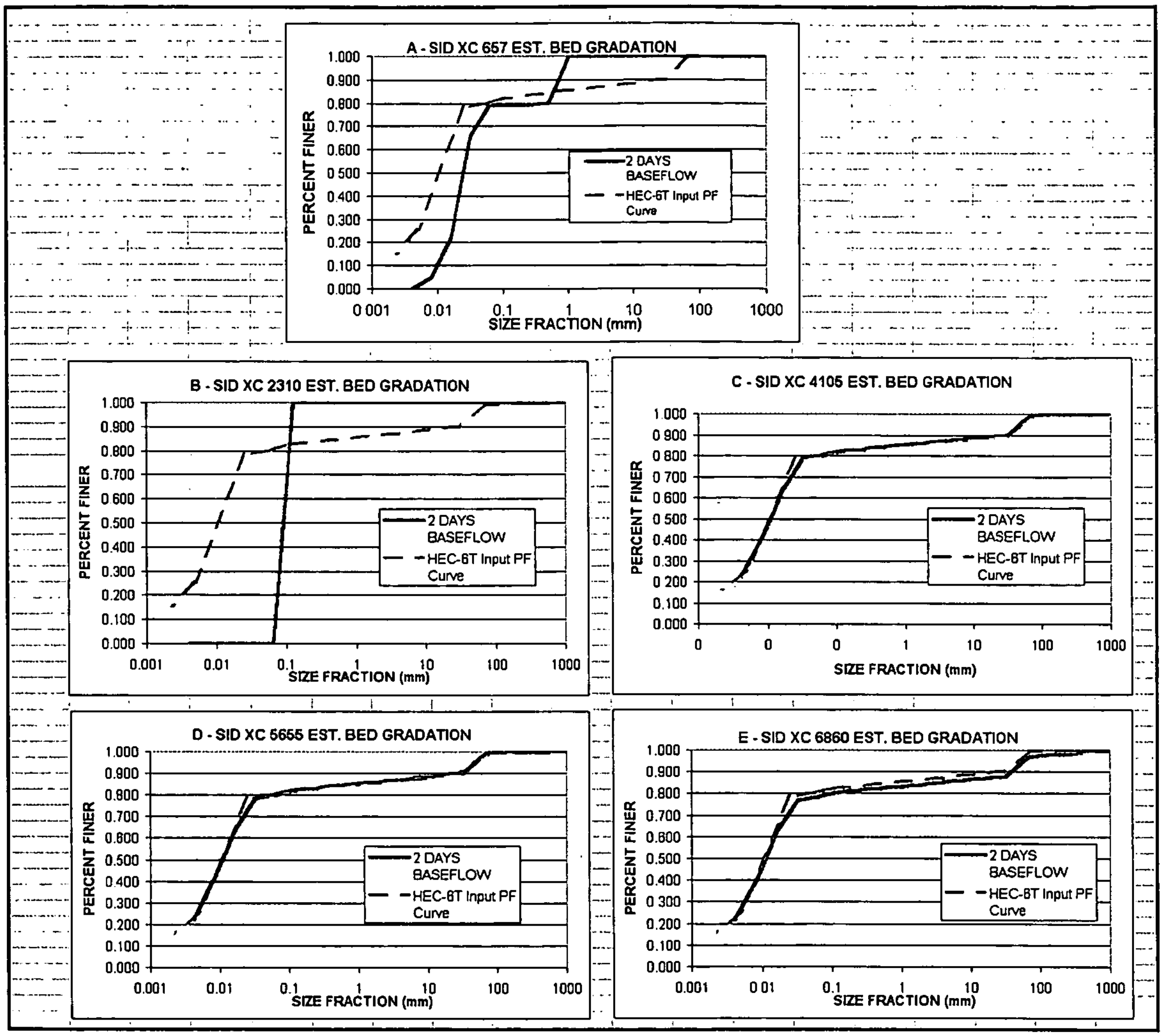
The number of base flow time steps varied depending on the watershed that was being modeled. Time steps varied from two to eight days, and base flow flows varied from 0.01 to 0.07 cfs. These values are lower than typical base flow values normally used in HEC-6T (as indicated by Tony Thomas). However, they do correspond with low base flows that are typical of each site location. The shallow erodible sediment depths in the site channels require only short base flow duration and low base flows to bring the model streambed into equilibrium with the flow. The effect of changing particle size distributions for the base flow inflows was also examined but was determined to have no effect on the calibration of the modeled watersheds.

2.2 Walnut Creek

The model calibration approach described above was applied to Walnut Creek with limited success. Figure E-6 shows the best model calibration fit that was obtained for Walnut Creek. A wide range of base flow time steps, flows and bed gradations were tested, yet a reasonable calibration appeared to be unattainable when base flow preceded the runoff hydrograph in the model. All model calibration runs consistently predicted a deficit of clay and silt-sized sediment. As a result, no base flow time steps were added to the Walnut Creek Watersheds, and the model was assumed to be initially at equilibrium. If this assumption is false, then the model will only overestimate sediment yields, which will conservatively overestimate actinide concentrations.

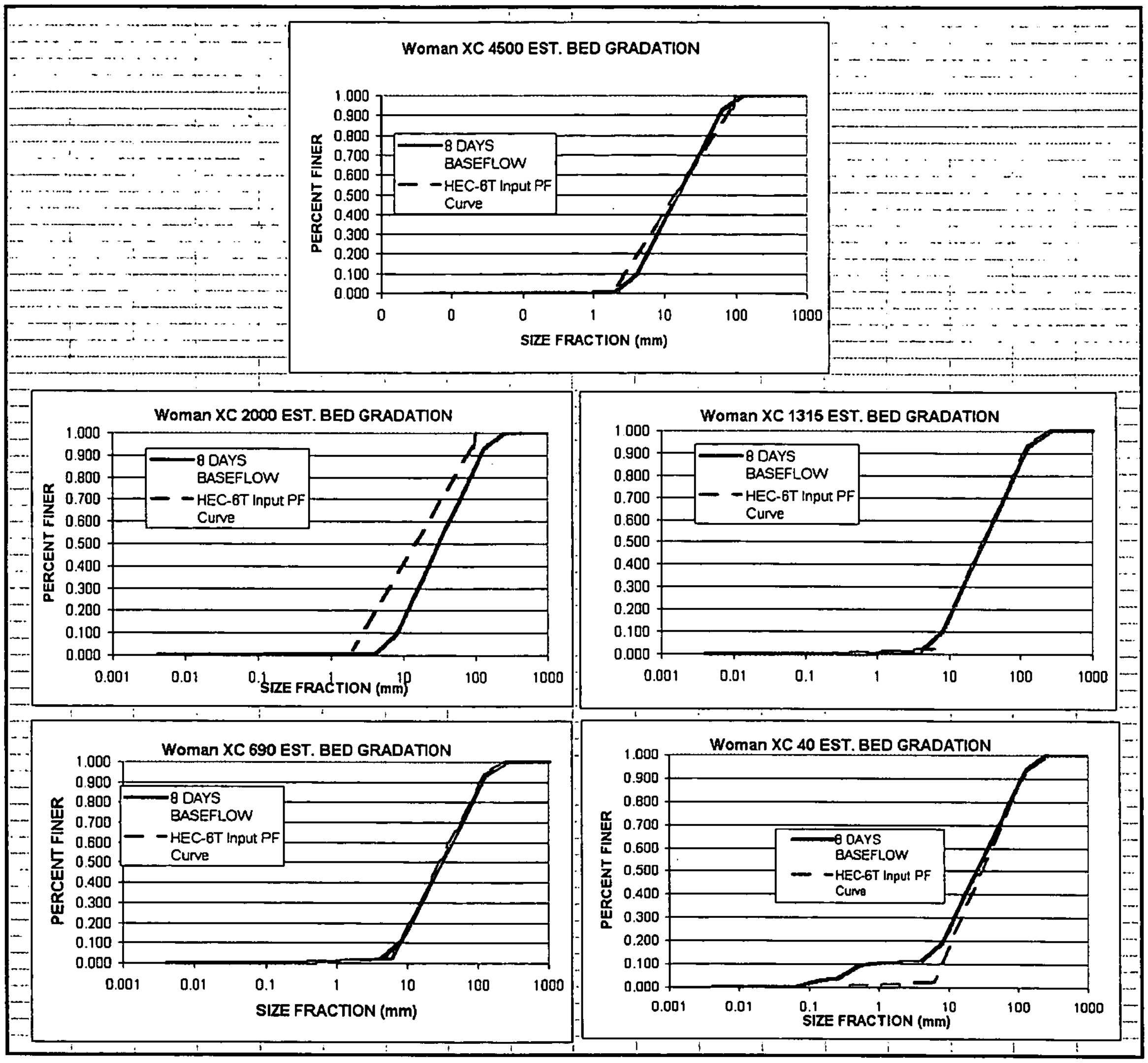
191

Figure E-3. Predicted vs. Actual Bed Gradation With Two Days of Base Flow for the South Interceptor Ditch (Graphs Run From Upstream to Downstream)



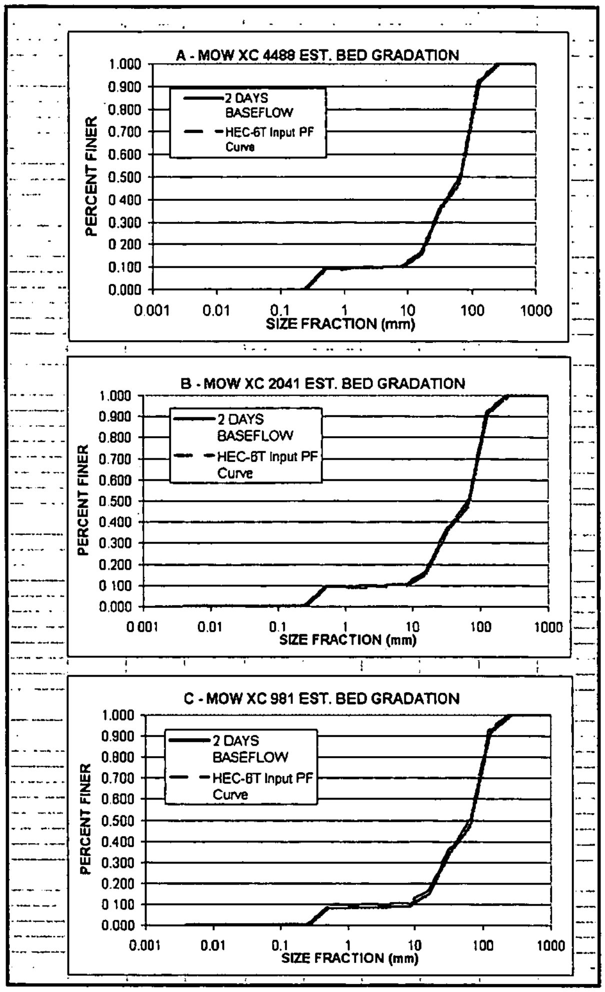
92

Figure E-4. Predicted vs. Actual Bed Gradation With Eight Days of Base Flow for Woman Creek (Graphs Run From Upstream to Downstream)



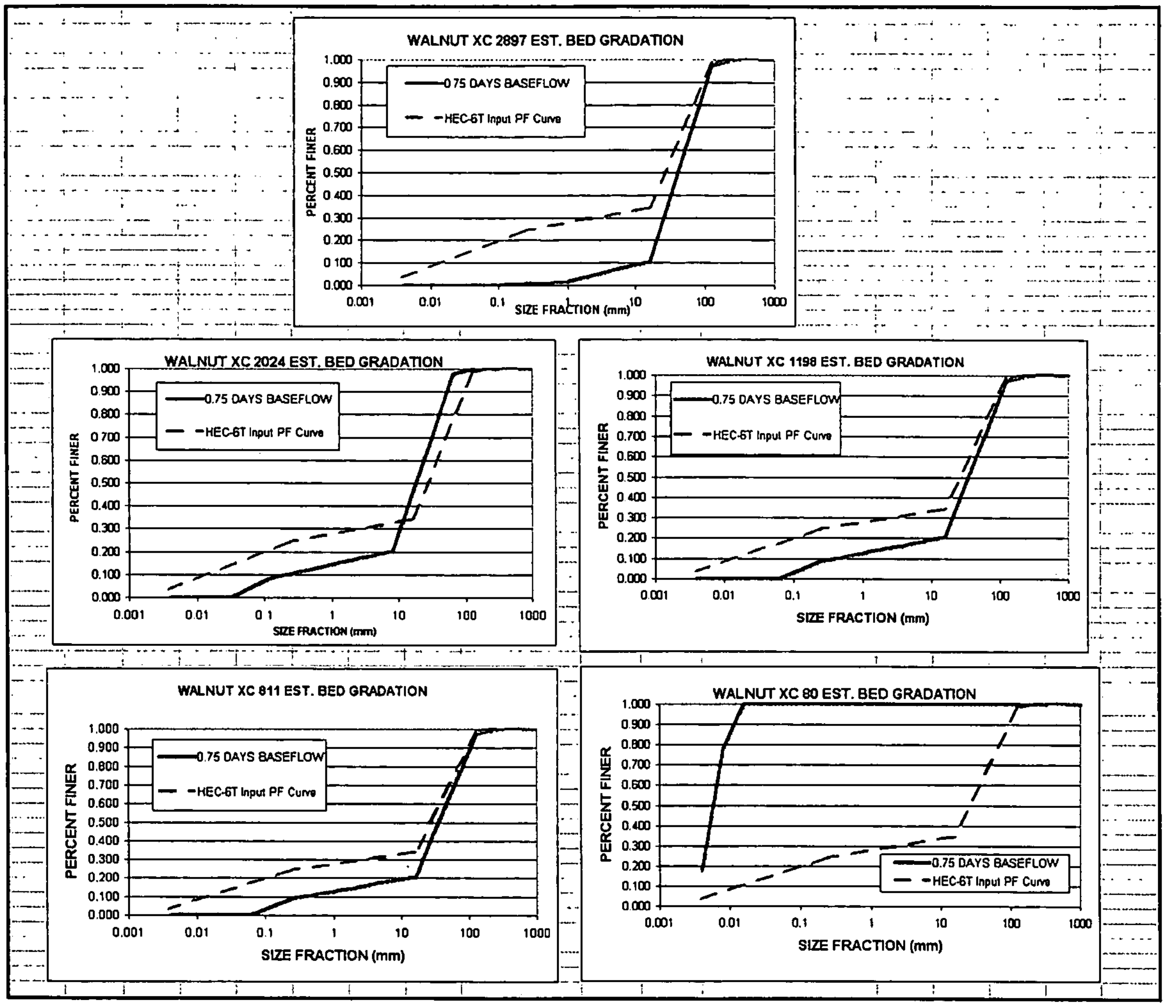
193

Figure E-5. Predicted vs. Actual Bed Gradation With Two Days of Base Flow for the Mower Ditch (Graphs Run From Upstream to Downstream)



194

Figure E-6. Predicted vs. Actual Bed Gradation With 0.75 (Q = 0.02 cfs) days of Base Flow for Walnut Creek (Graphs Run From Upstream to Downstream)



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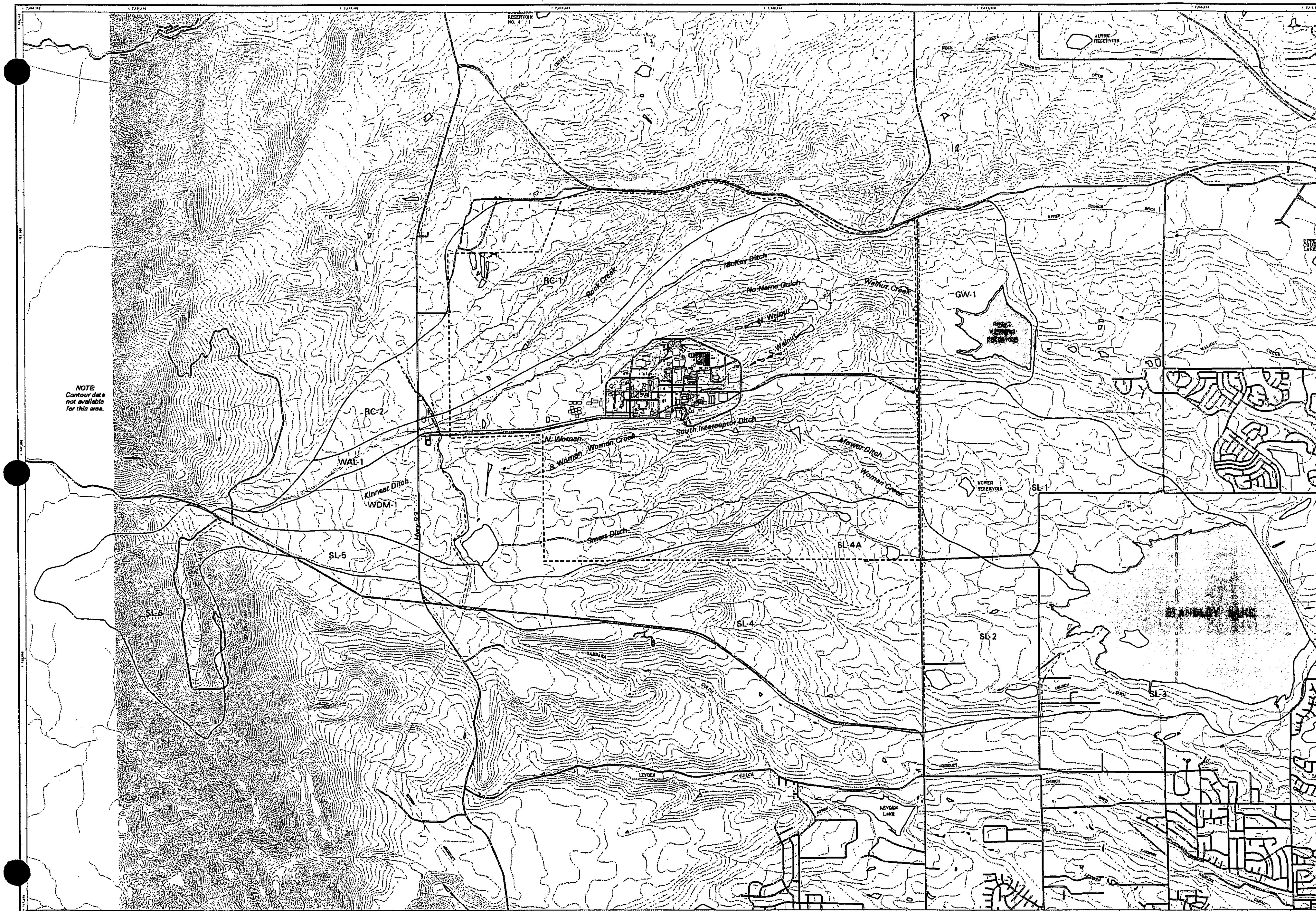

Figure 1

Major Drainage Basins at Rocky Flats

EXPLANATION

Major Drainage Basin Boundary

Sub-Basin Boundary

Areas of Sub-basins

Rock Creek 1 - 1662.9 Acres

Rock Creek 2 - 219.5 Acres

Walnut Creek 1 - 143.2 Acres

Woman Creek 1 - 563.7 Acres

Great Western 1 - 594.0 Acres

Standley Lake 1 - 1537.2 Acres

Standley Lake 2 - 939.4 Acres

Standley Lake 3 - 428.8 Acres

Standley Lake 4 - 1806.3 Acres

Standley Lake 4A - 528.4 Acres

Standley Lake 5 - 380.7 Acres

Standley Lake 6 - 912.2 Acres

Standard Map Features

Buildings and other structures

Solar Evaporation Ponds (SEP)

Lakes and ponds

Streams, ditches, or other drainage features

Rocky Flats boundary

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95
Data Source:
Drainage Basin data - Approved by Win Chromec (RMRS, 303-966-4535).

Scale = 1 : 48180
1 inch represents approximately 4088 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy

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NT Svr w:/projects/fy2k/2k-0069/basins.aml

90

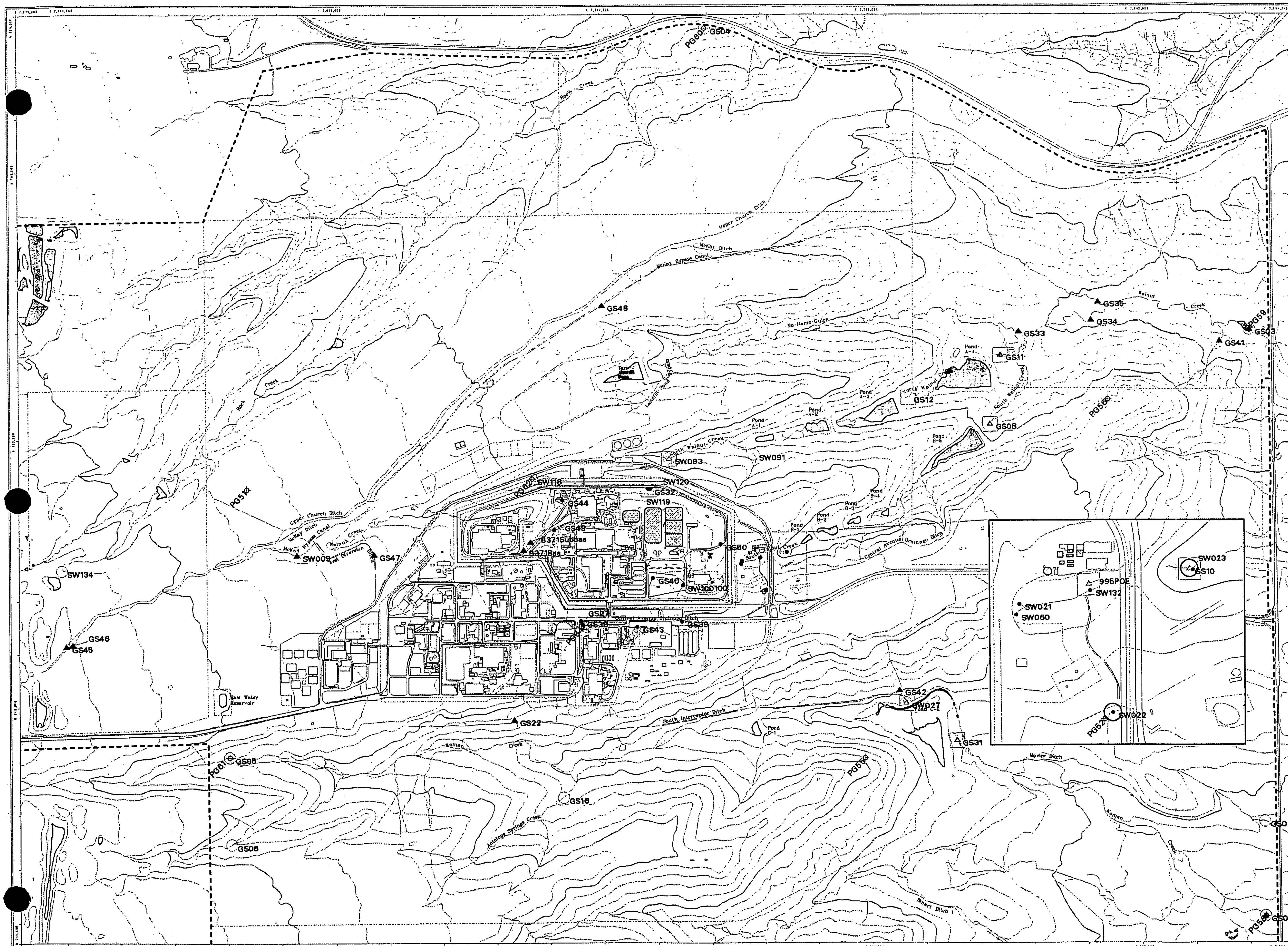

Figure 3

Automated Surface Water Monitoring Locations and Precipitation Gages for FY 2001

EXPLANATION

Precipitation Gage

Monitoring Location Objective*

- Buffer Zone Hydrologic
- New Source Detection
- Point of Compliance
- Point of Evaluation
- Source Location
- Ad Hoc
- Performance
- IDLH**

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Rocky Flats boundary
- Paved roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. DEM post-processing performed by MK, Winter 1997.

NOTE:
* The monitoring objective(s) performed at each location are detailed in the Surface Water Section of the Site Integrated Monitoring Plan.

** IDLH (Immediate Danger to Life & Health) refers to the monitoring objective for safe operation of the Site detention ponds.

N

Scale = 1 : 17870
1 inch represents approximately 1489 feet

250 0 500 1000 Feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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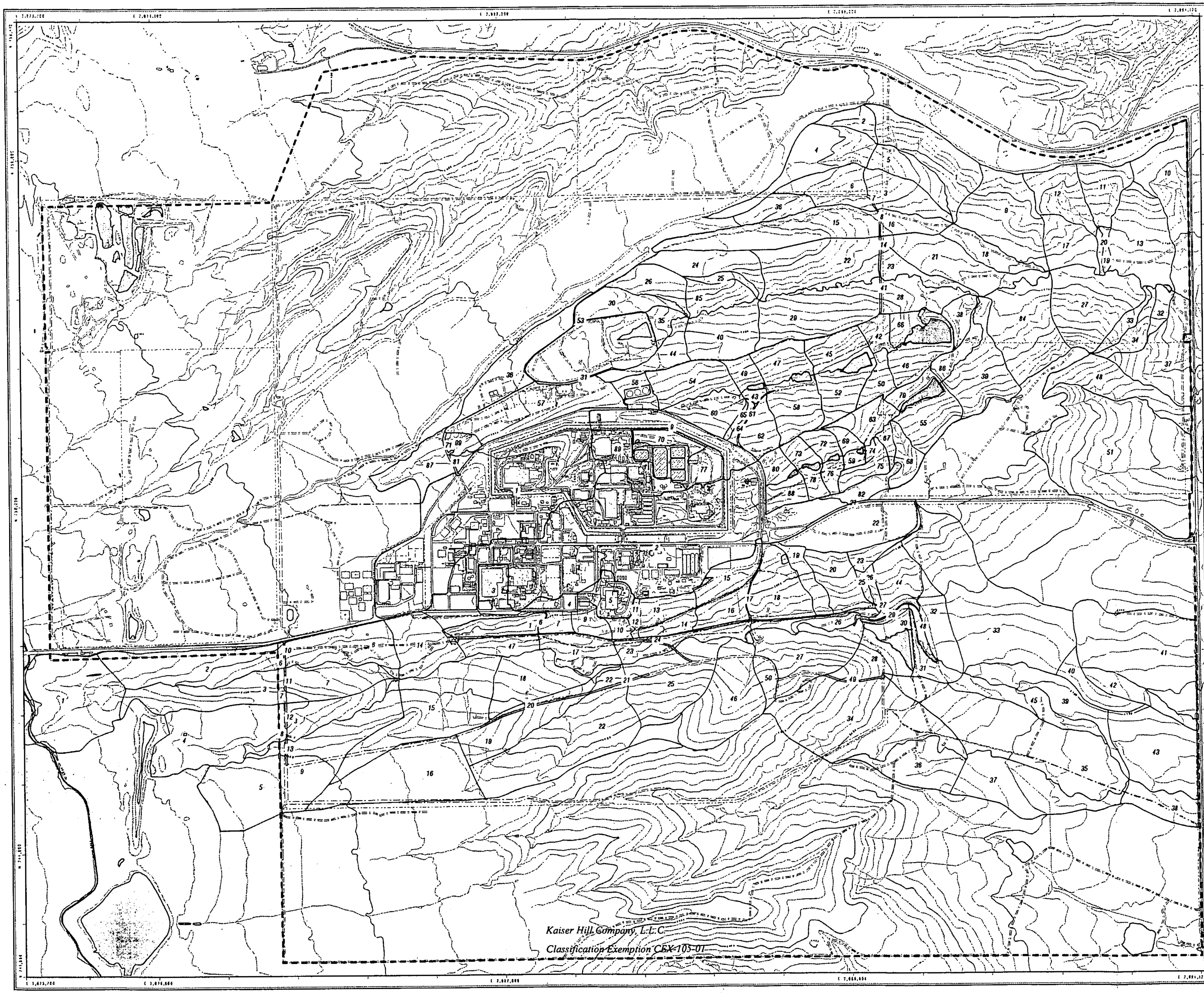


Figure 4

All Watershed Hillslopes

EXPLANATION

Hillslope Boundaries

- Woman Creek Watershed Hillslopes
- South Interceptor Ditch Hillslopes
- Walnut Creek Watershed Hillslopes

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (20-Foot)
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours.
The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution.
DEM post-processing performed by MK, Winter 1997.

Scale = 1 : 21330
1 inch represents approximately 1778 feet

500 0 1000 2000ft

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

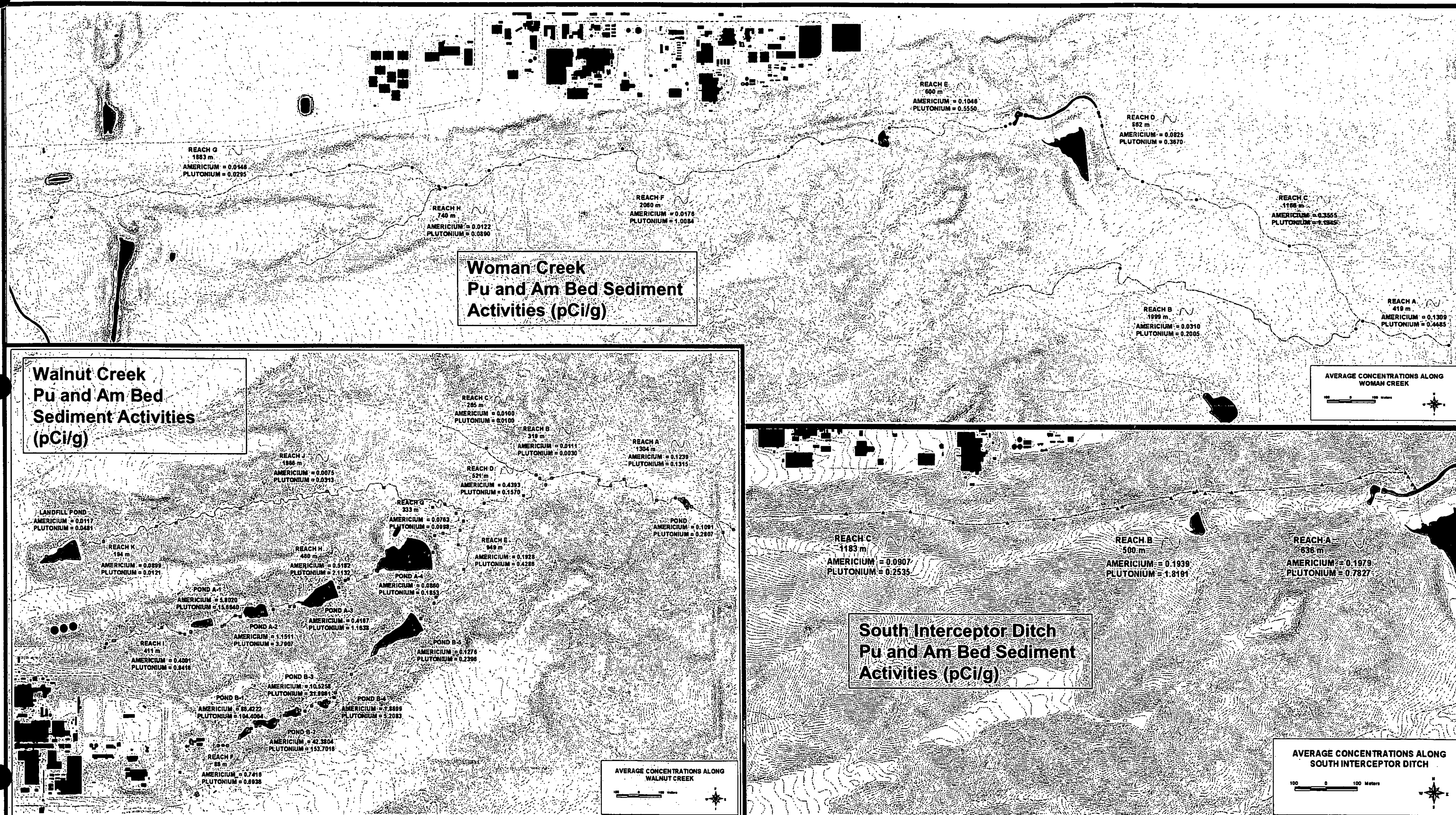
U.S. Department of Energy
Rocky Flats Environmental Technology Site

Rocky Mountain Remediation Services, L.L.C.
Geographic Information Systems Group
Rocky Flats Environmental Technology Site
P.O. Box 464
Golden, CO 80402-0464

MAP ID: 2k-0069 December 01, 1999

93

Figure 8. Pu and Am Activity in Bed Sediments for Walnut Creek, the South Interceptor Ditch and Woman Creek



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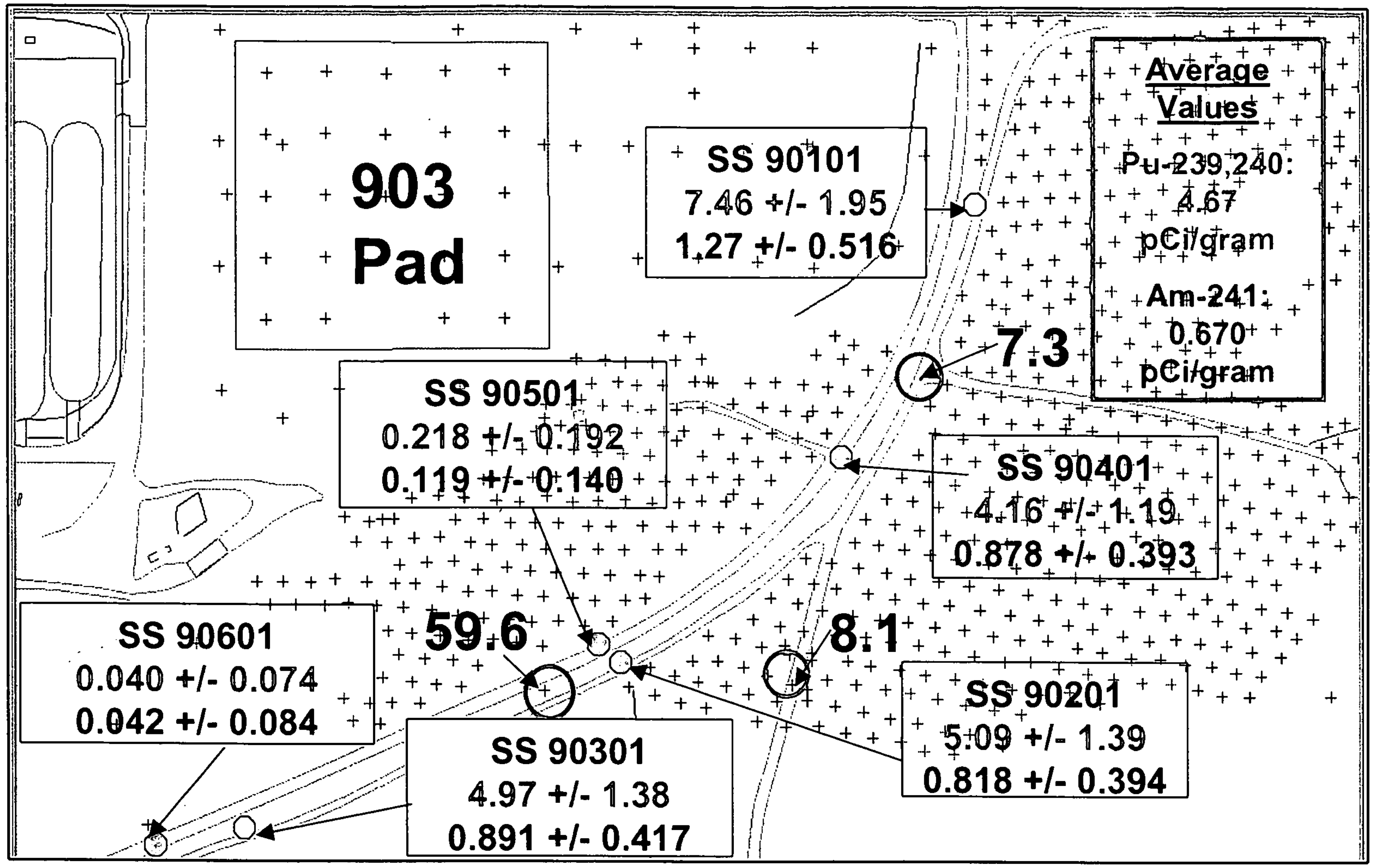

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Figure 15. Data for Surface Soil Actinide Content for 903 Pad and Lip Area Roads.

EXPLANATION

SS 90401
4.16 +/- 1.19
0.878 +/- 0.393

FY01 Sampling Location Code

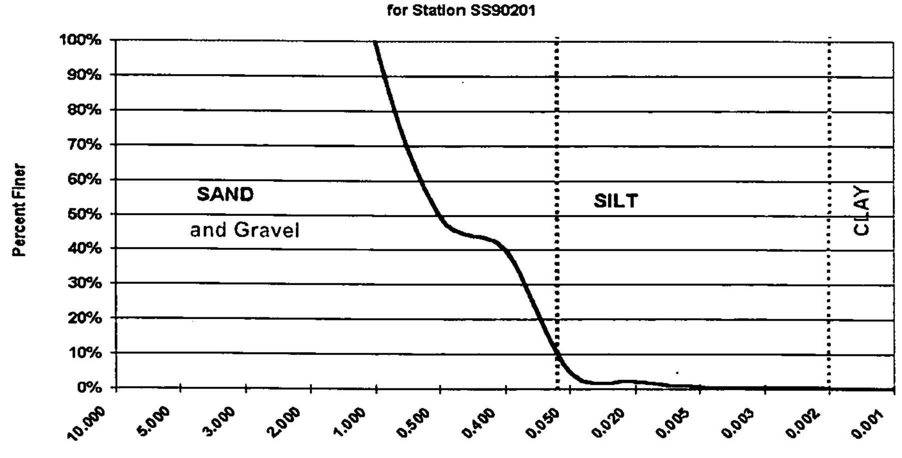
Pu-239,240(pCi/gram)

Am-241 (pCi/gram)

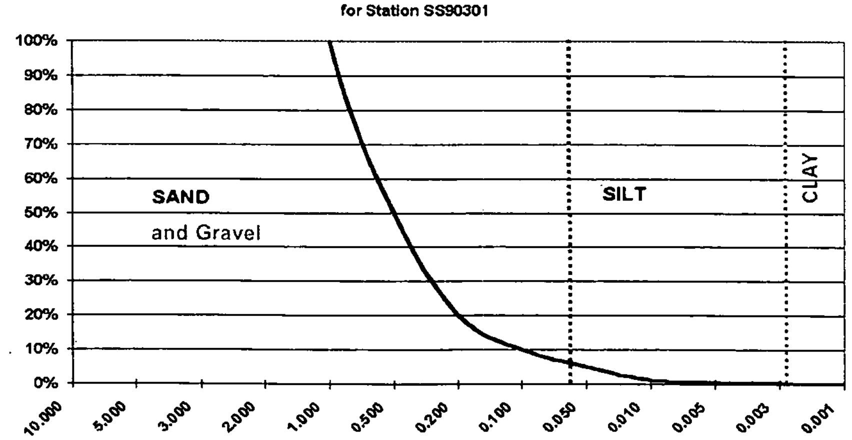
8.1

903 Pad Characterization Pu-239,240 Measurement (pCi/gram)

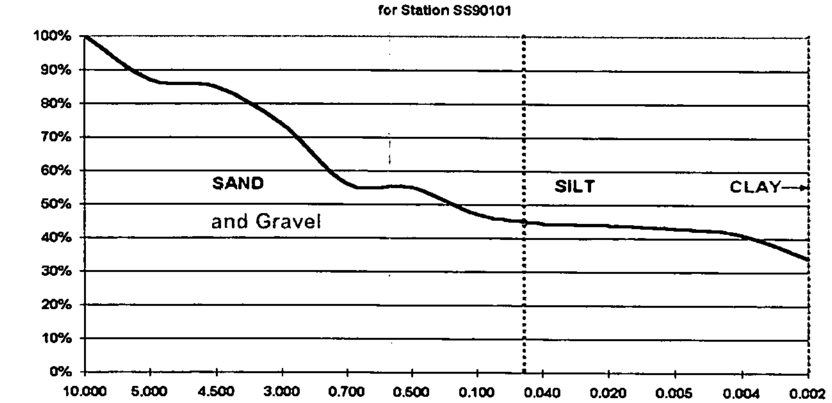
Particle Size Distribution for Station SS90201

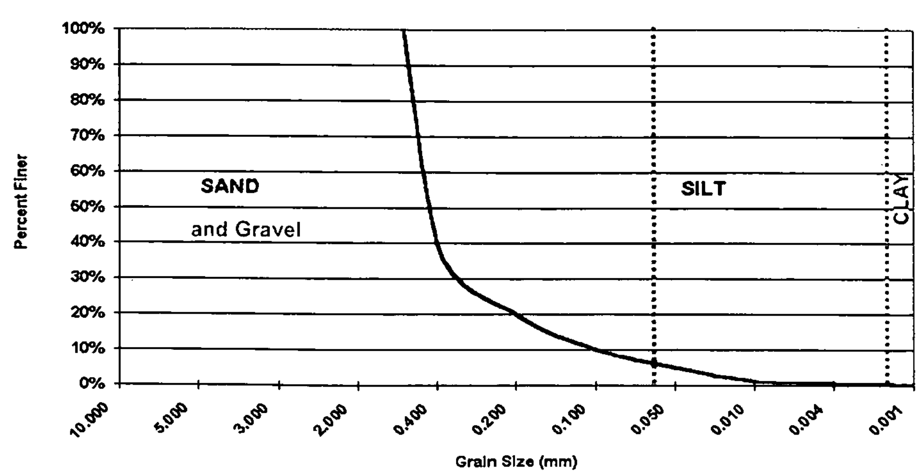


Particle Size Distribution for Station SS90301

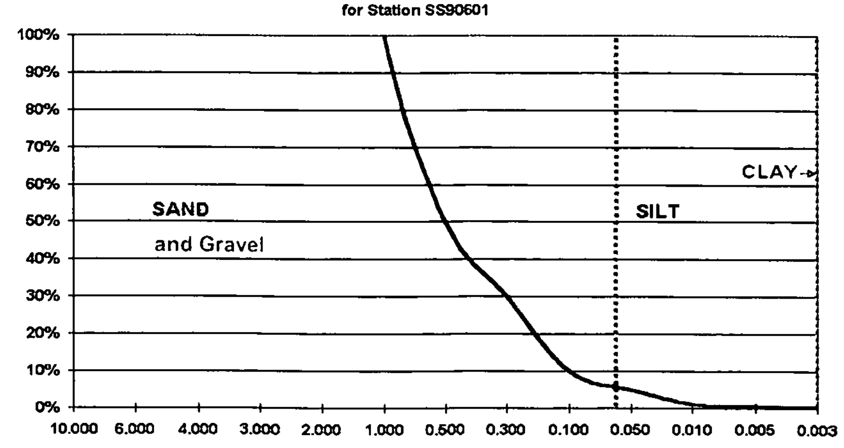


Particle Size Distribution for Station SS90101





Particle Size Distribution for Station SS90601



Particle Size Distribution for Station SS90401

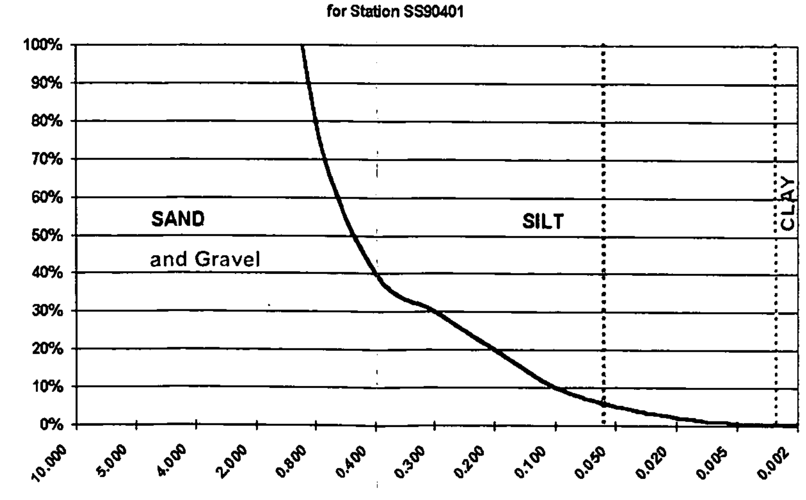


Figure 16.
Pu-239,240 in Surface Soil - Variations of Kriged Isoplot Grids Near 903 Pad

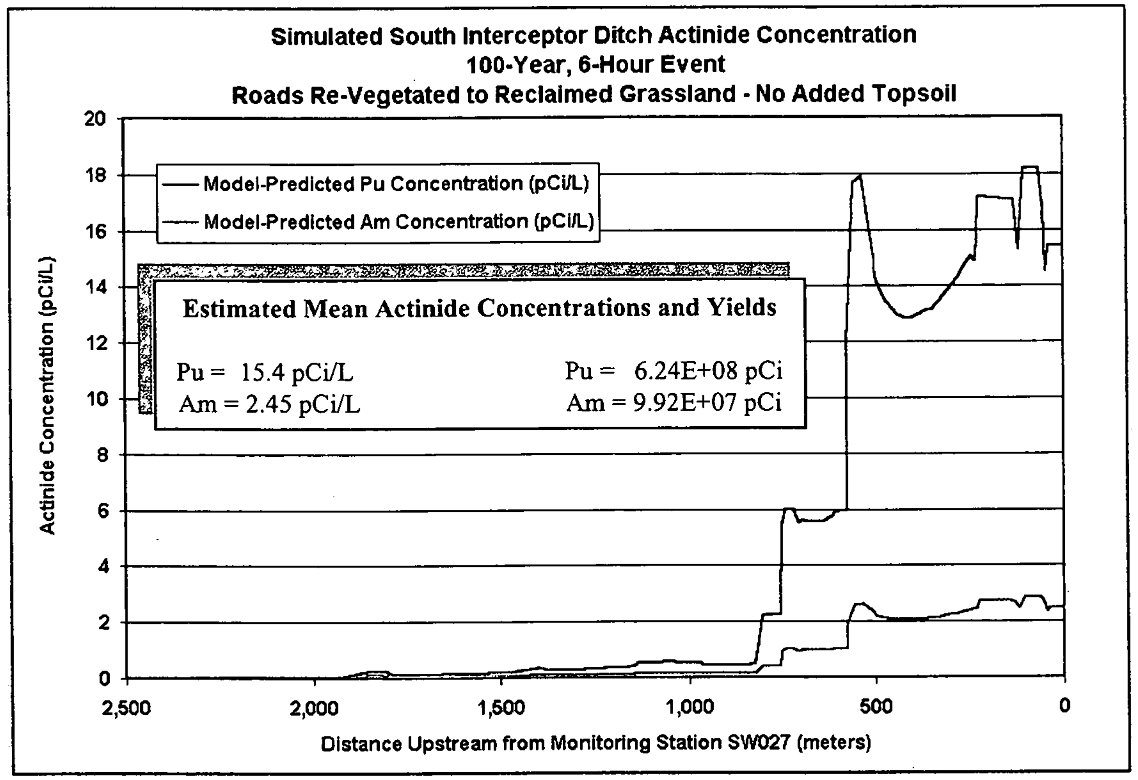
Original surface soil Pu kriging analysis presented in the 2000 Erosion Report.

Original surface soil Pu kriging analysis modified with dirt road sample data collected on 5/17/01.

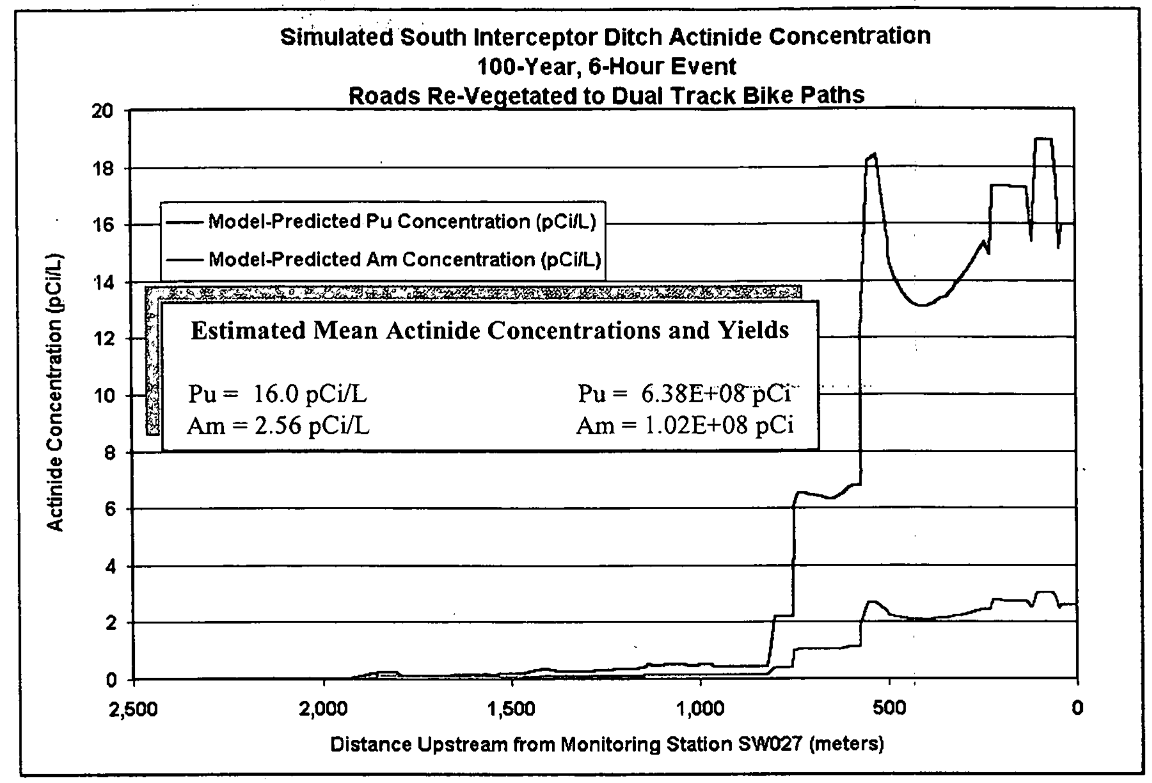
Original surface soil Pu kriging analysis edited with simulated road re-grading and re-vegetation.

Figure 17. Comparison of Road Re-vegetation Scenarios for the SID

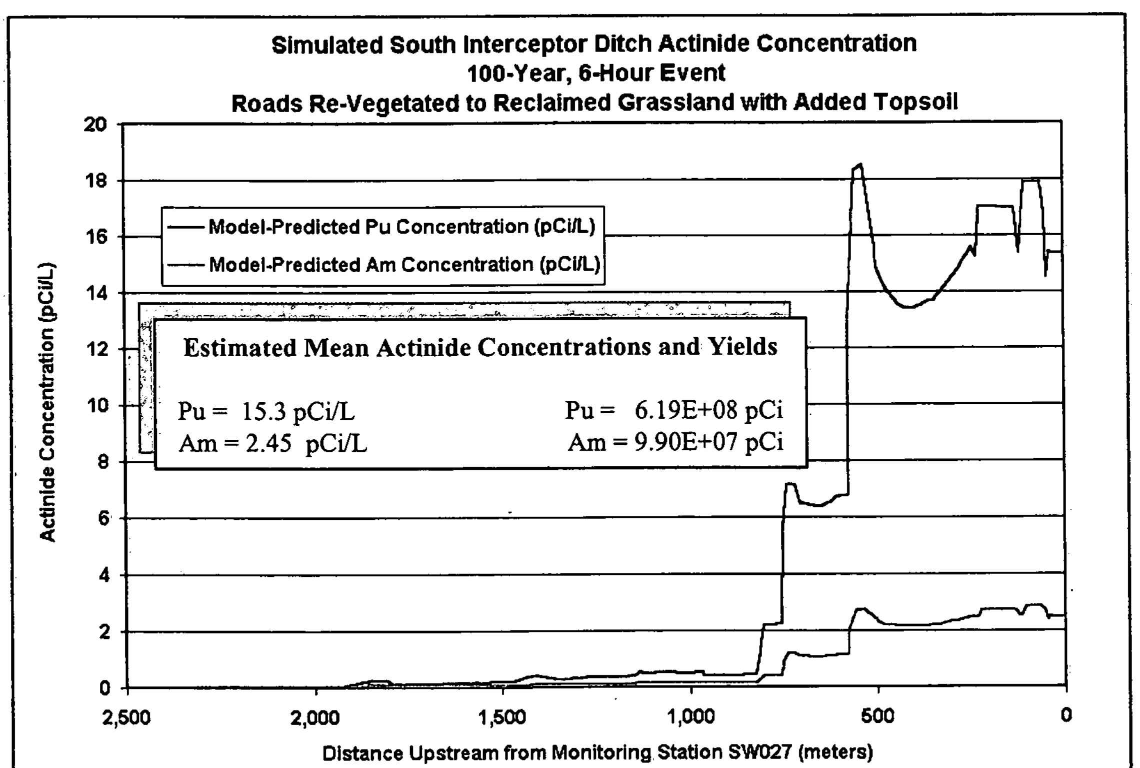
Complete Road Re-vegetation - No Added Topsoil



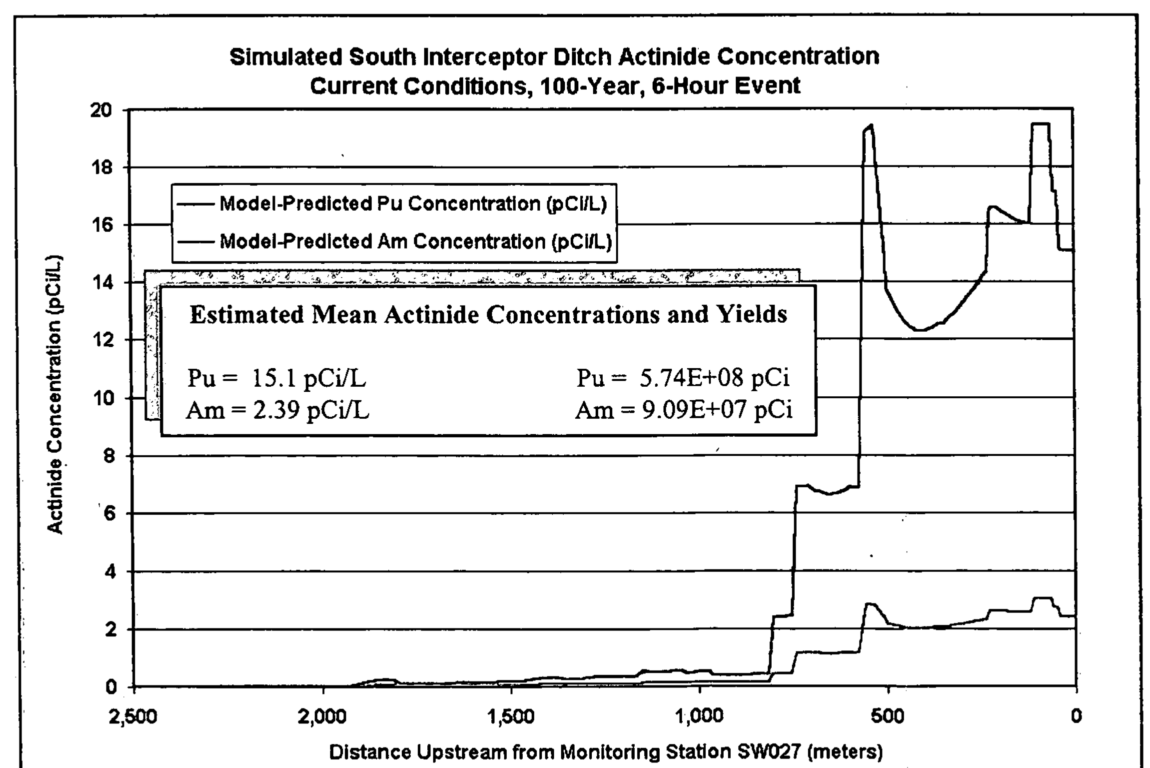
Road Re-vegetation to Dual Track Bike Paths - No Added Topsoil



Complete Road Re-vegetation - Added Topsoil



Existing Conditions



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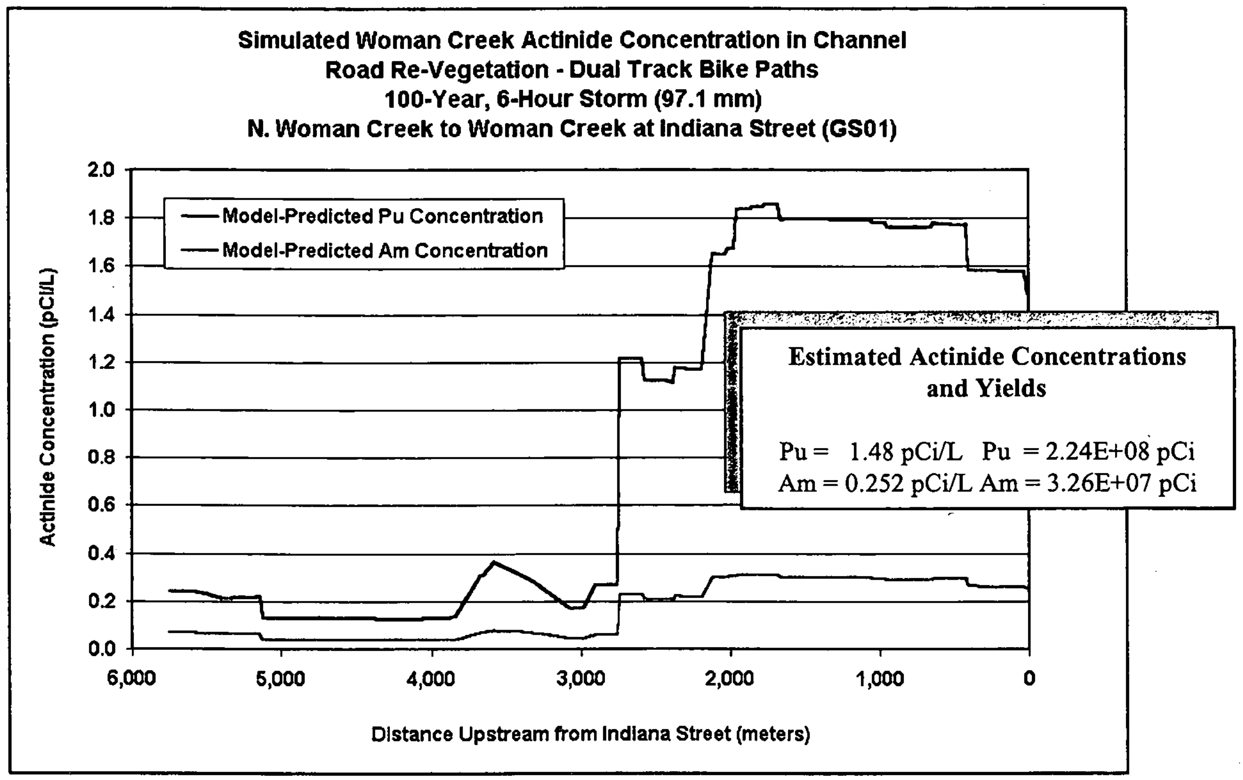
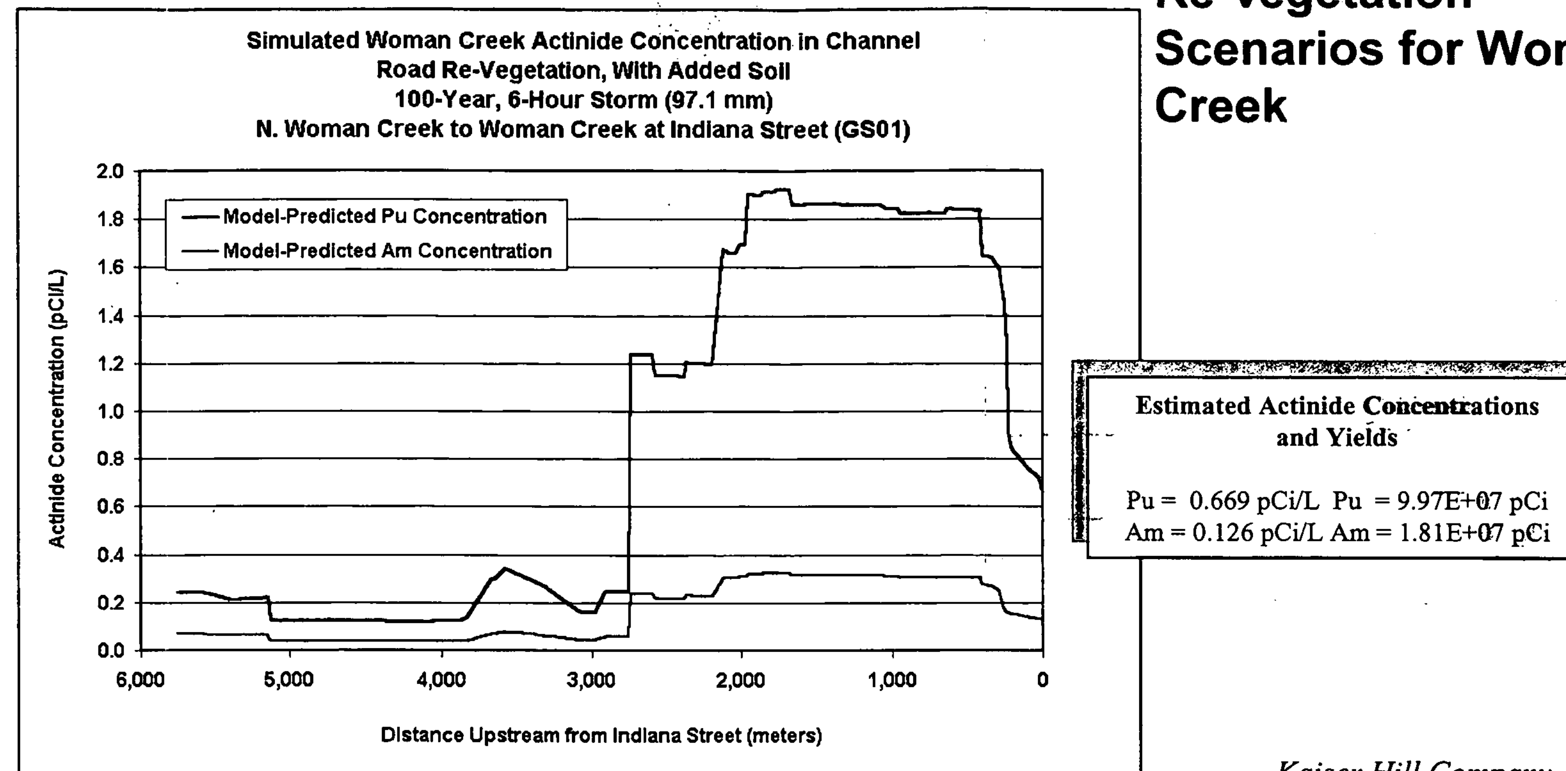
106

Figure 18. Comparison of Road Re-vegetation Scenarios for Woman Creek

Road Re-vegetation to Dual Track Bike Paths - No Added Topsoil



Complete Road Re-vegetation - Added Topsoil



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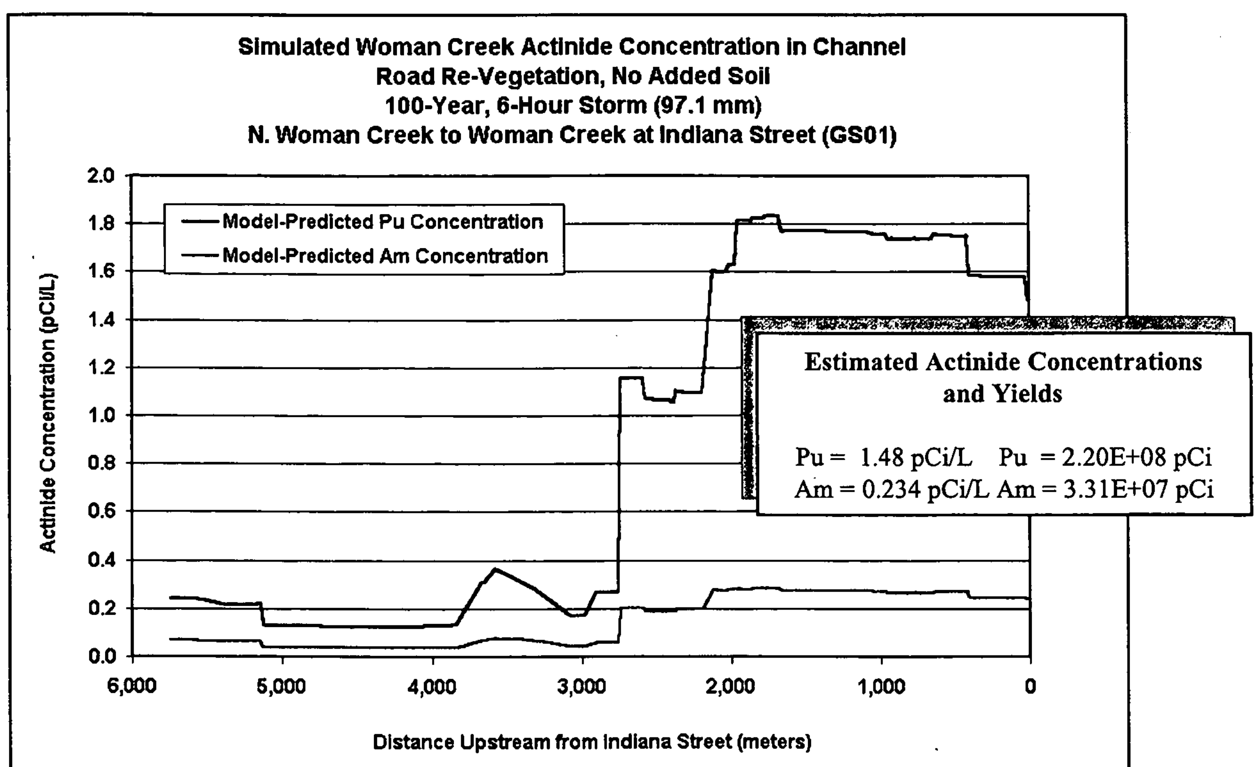
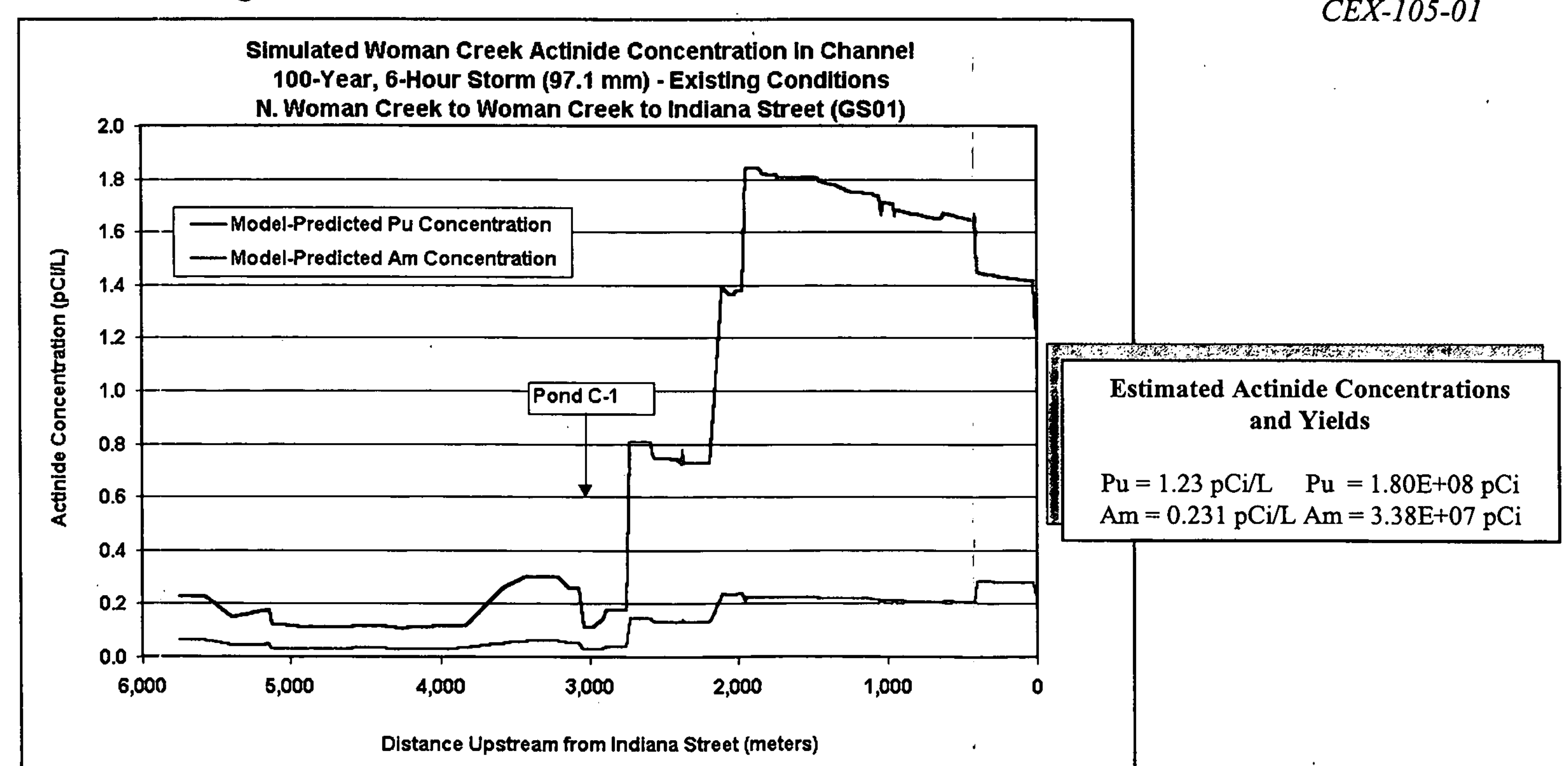
Complete Road Re-vegetation - No Added Topsoil



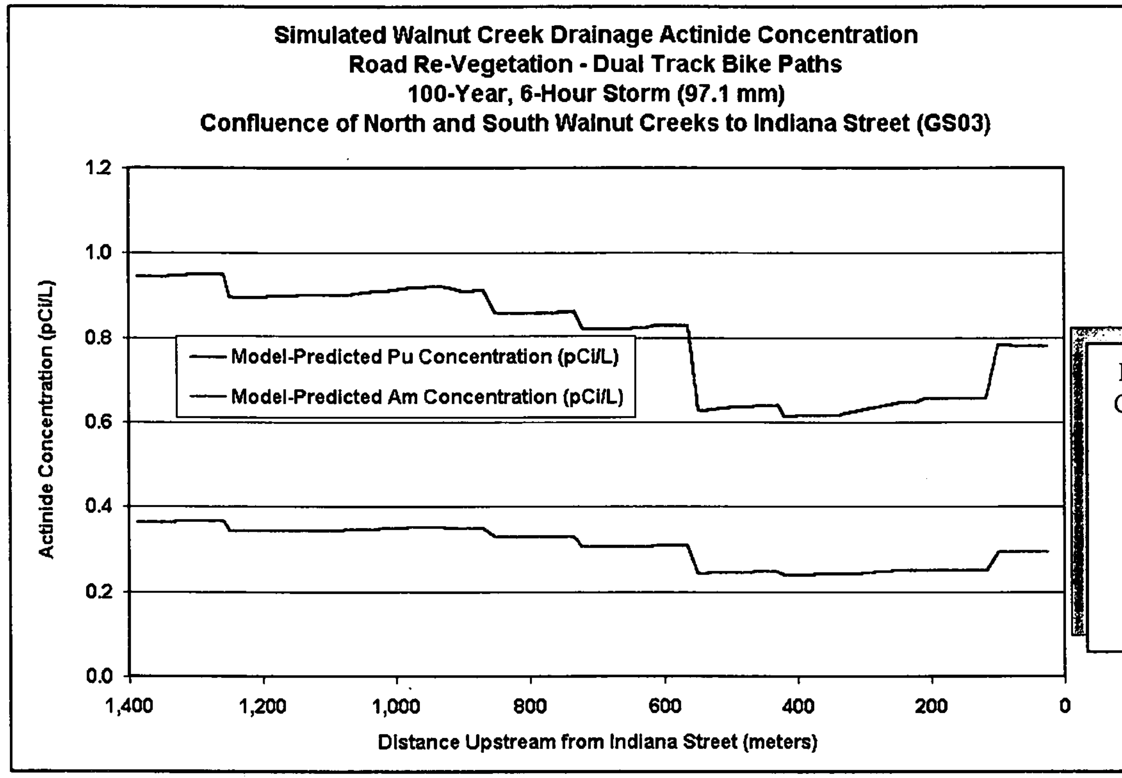
Existing Conditions



107

Figure 19. Comparison of Road Re-vegetation Scenarios for Walnut Creek

Road Re-vegetation to Dual Track Bike Paths - No Added Topsoil

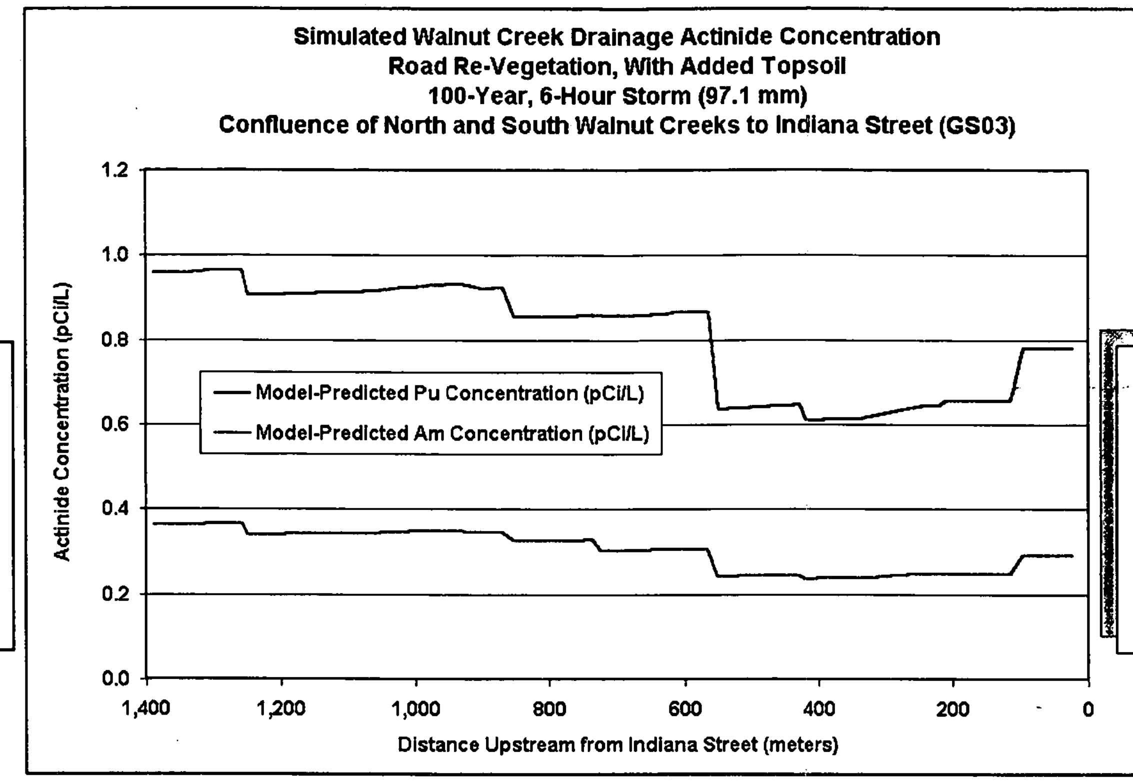


Estimated Mean Actinide Concentrations and Yields at Indiana Street

Pu = 0.790 pCi/L
Am = 0.291 pCi/L

Pu = 1.45E+08 pCi
Am = 5.51E+07 pCi

Complete Road Re-vegetation - Added Topsoil

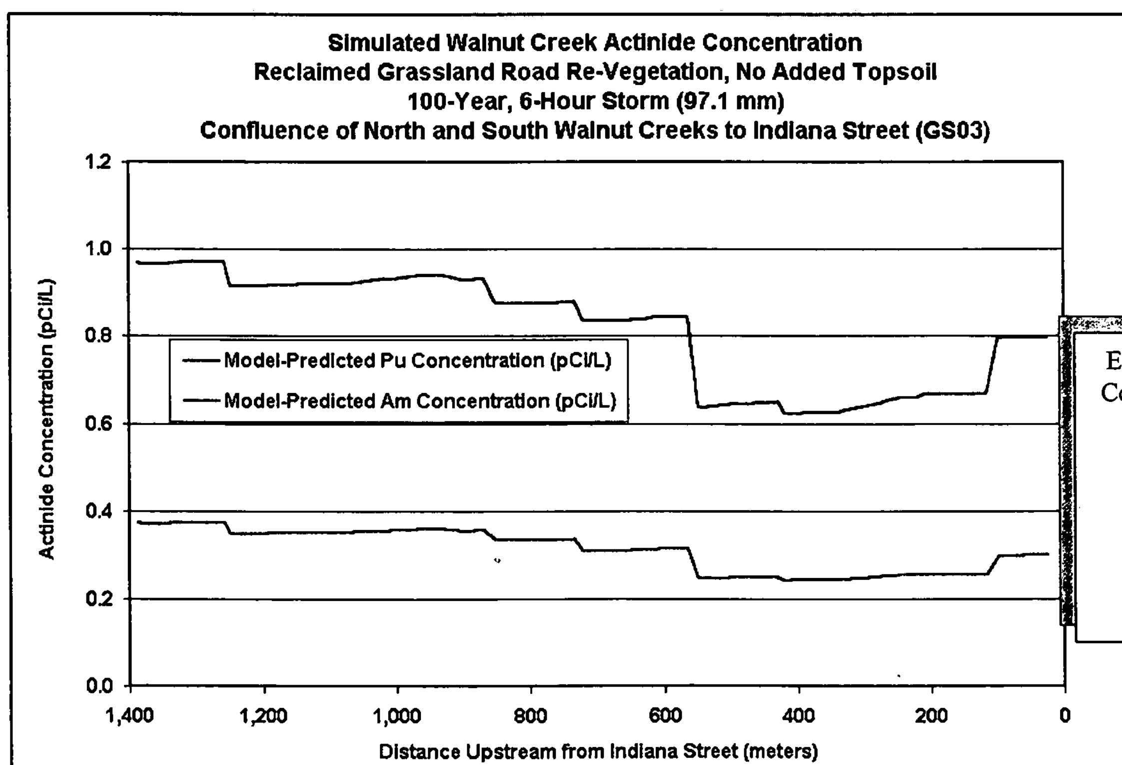


Estimated Mean Actinide Concentrations and Yields at Indiana Street

Pu = 0.780 pCi/L
Am = 0.290 pCi/L

Pu = 1.47E+08 pCi
Am = 5.46E+07 pCi

Complete Road Re-vegetation - No Added Topsoil

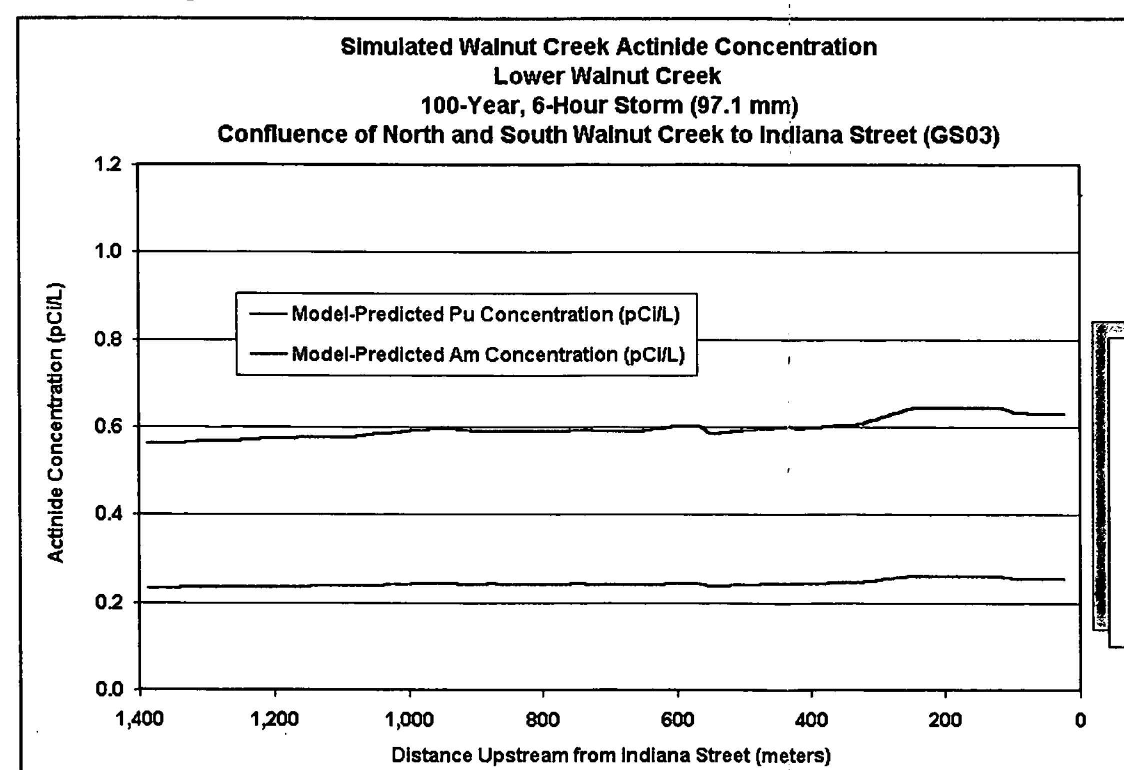


Estimated Mean Actinide Concentrations and Yields at Indiana Street

Pu = 0.796 pCi/L
Am = 0.297 pCi/L

Pu = 1.48E+08 pCi
Am = 5.40E+07 pCi

Existing Conditions



Estimated Mean Actinide Concentrations and Yields at Indiana Street

Pu = 0.629 pCi/L
Am = 0.253 pCi/L

Pu = 1.60E+08 pCi
Am = 6.43E+07 pCi

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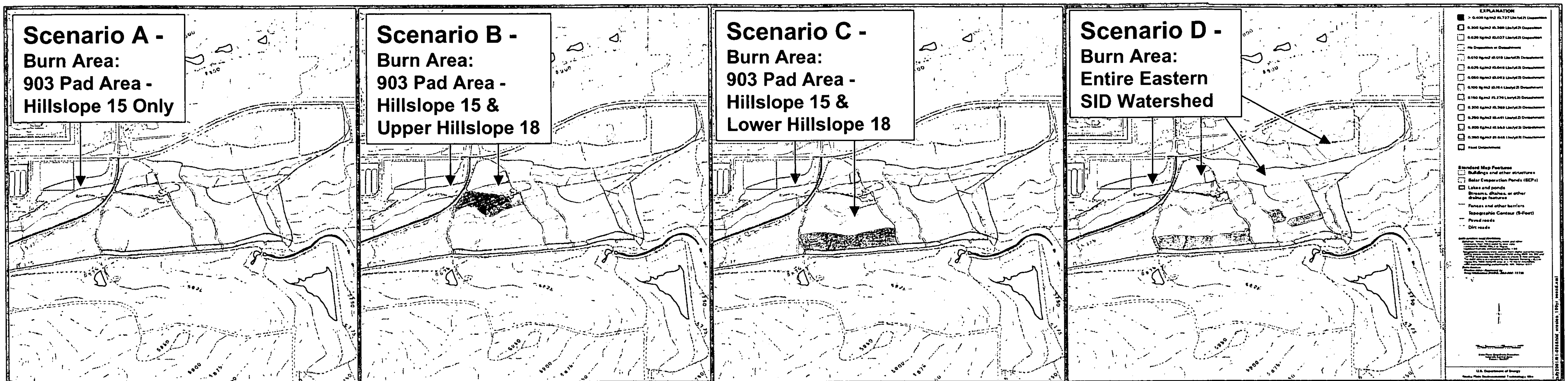
108

Figure 20. SID Range Fire Erosion Maps for the 100-Year, 6-Hour Storm (97.1-mm)



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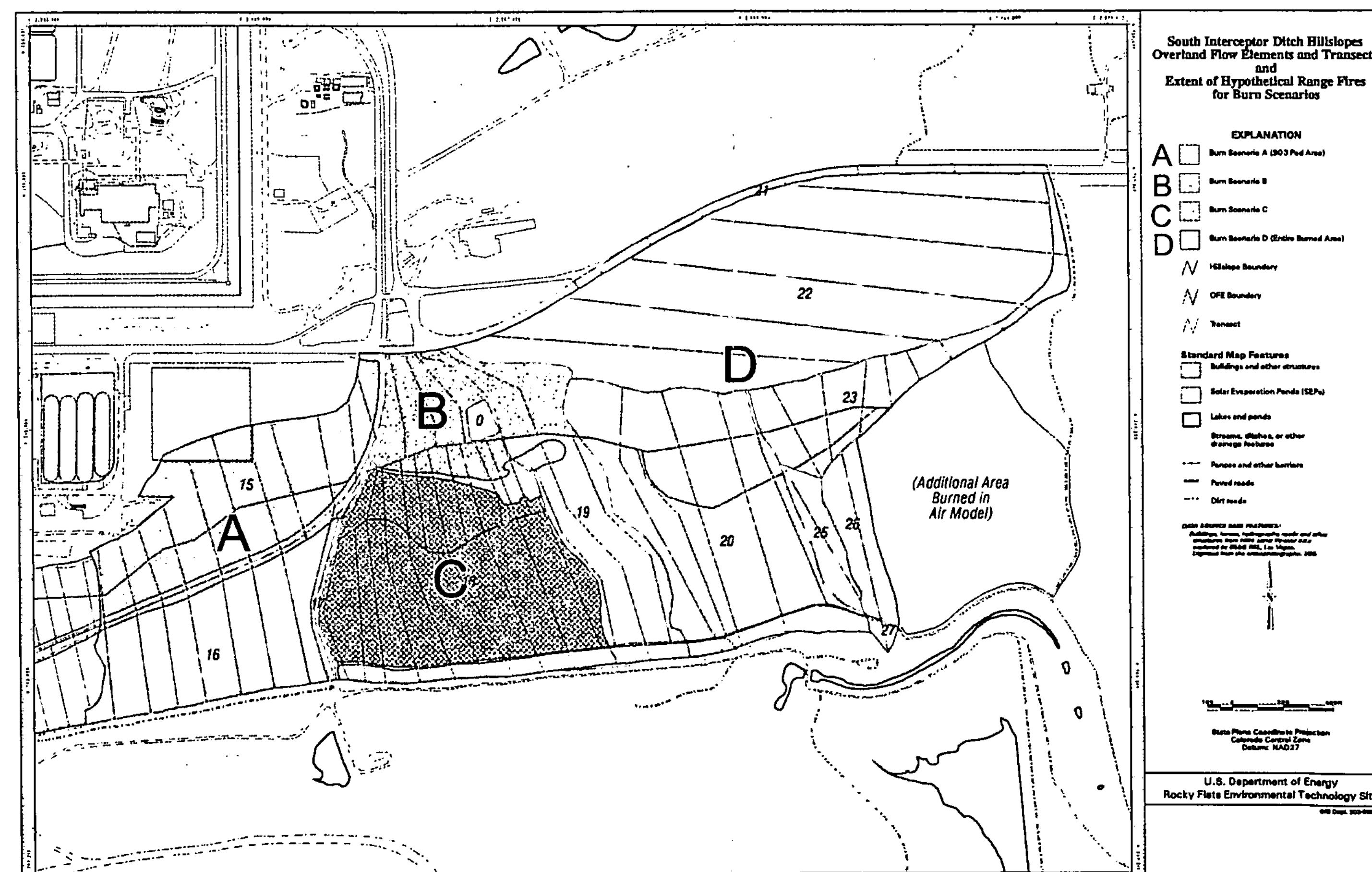
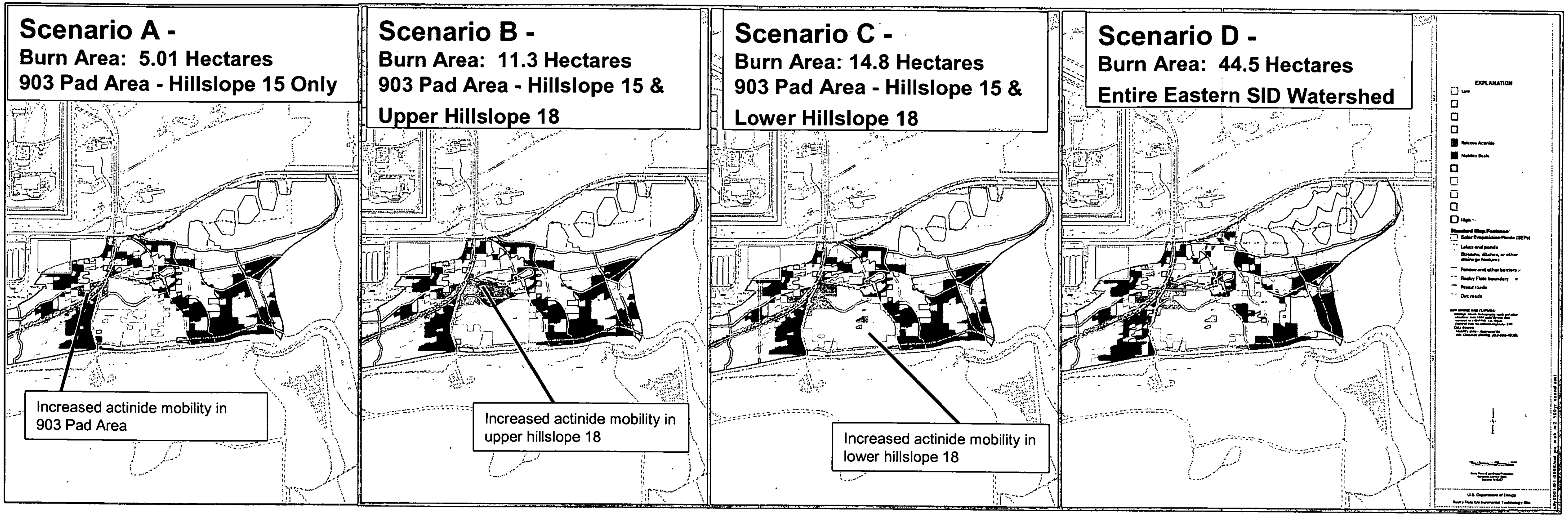
Burned area from lightening strike near the East Gate in 2000.



109

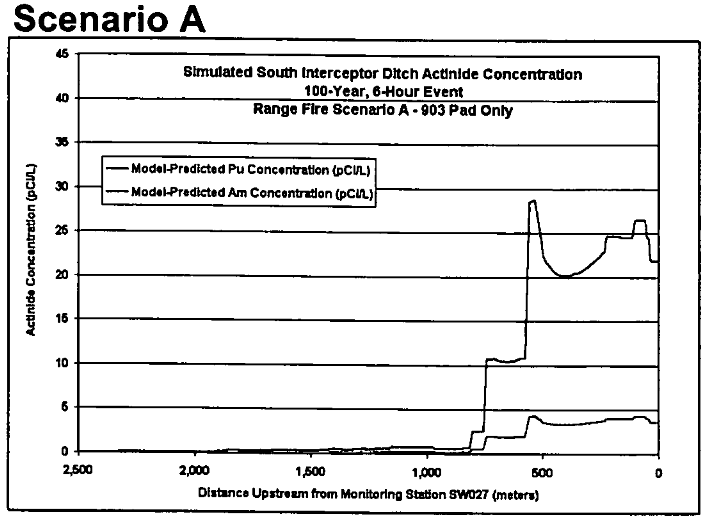
Figure 22. Range Fire Analysis - Impact on Pu and Am Mobility in South Interceptor Ditch Watershed, 100 Year, 6-Hour Storm (97.1-mm)

Pu and Am Mobility Caused by Soil Erosion

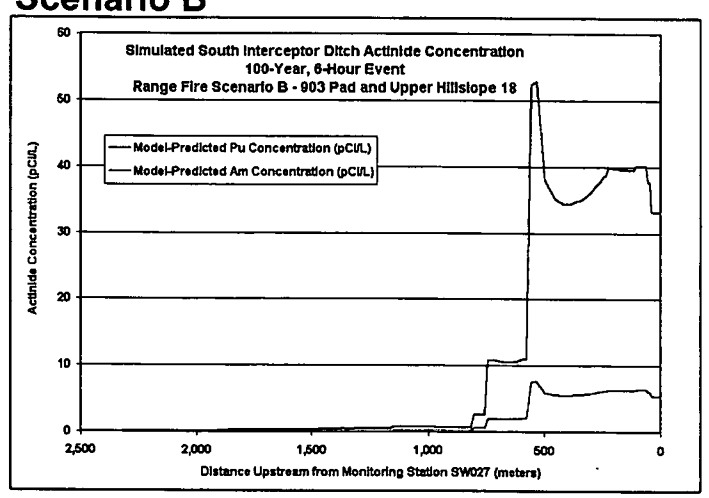


Corresponding Surface Water Pu and Am Concentrations and Yields

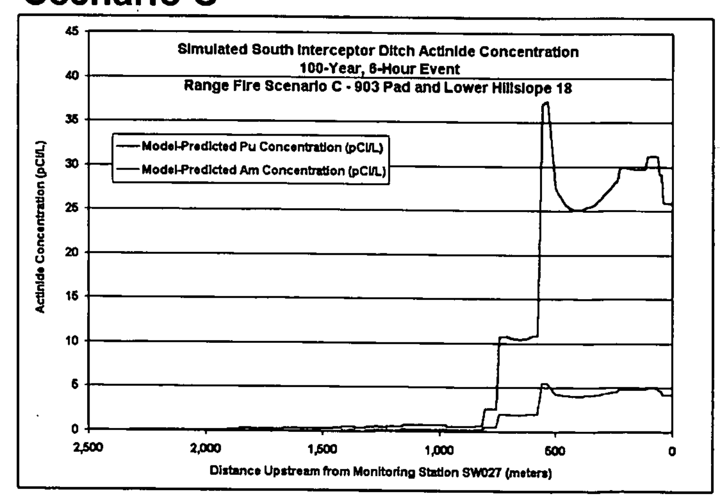
Scenario A



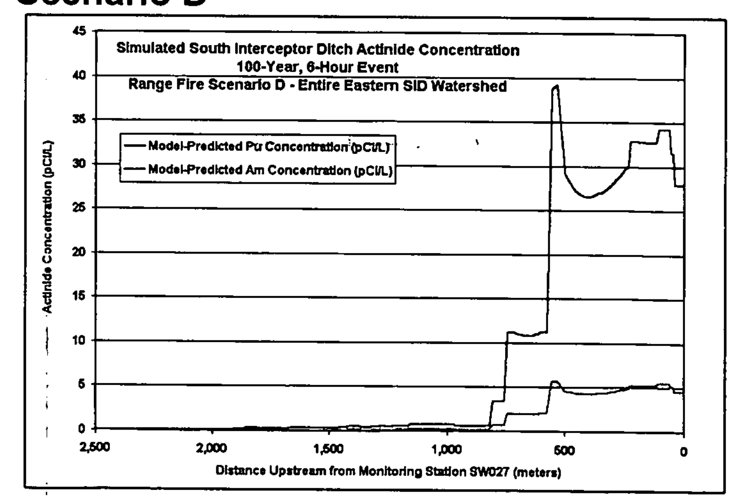
Scenario B



Scenario C



Scenario D



SID Scenarios	Estimated Runoff Yield (m^3)	Estimated Pu Yield (pCi)	Estimated Am Yield (pCi)
Unburned	38,086	5.74E+08	9.09E+07
A	38,401	8.53E+08	1.38E+08
B	39,126	1.31E+09	2.09E+08
C	39,812	1.05E+09	1.67E+08
D	44,310	1.25E+09	1.99E+08

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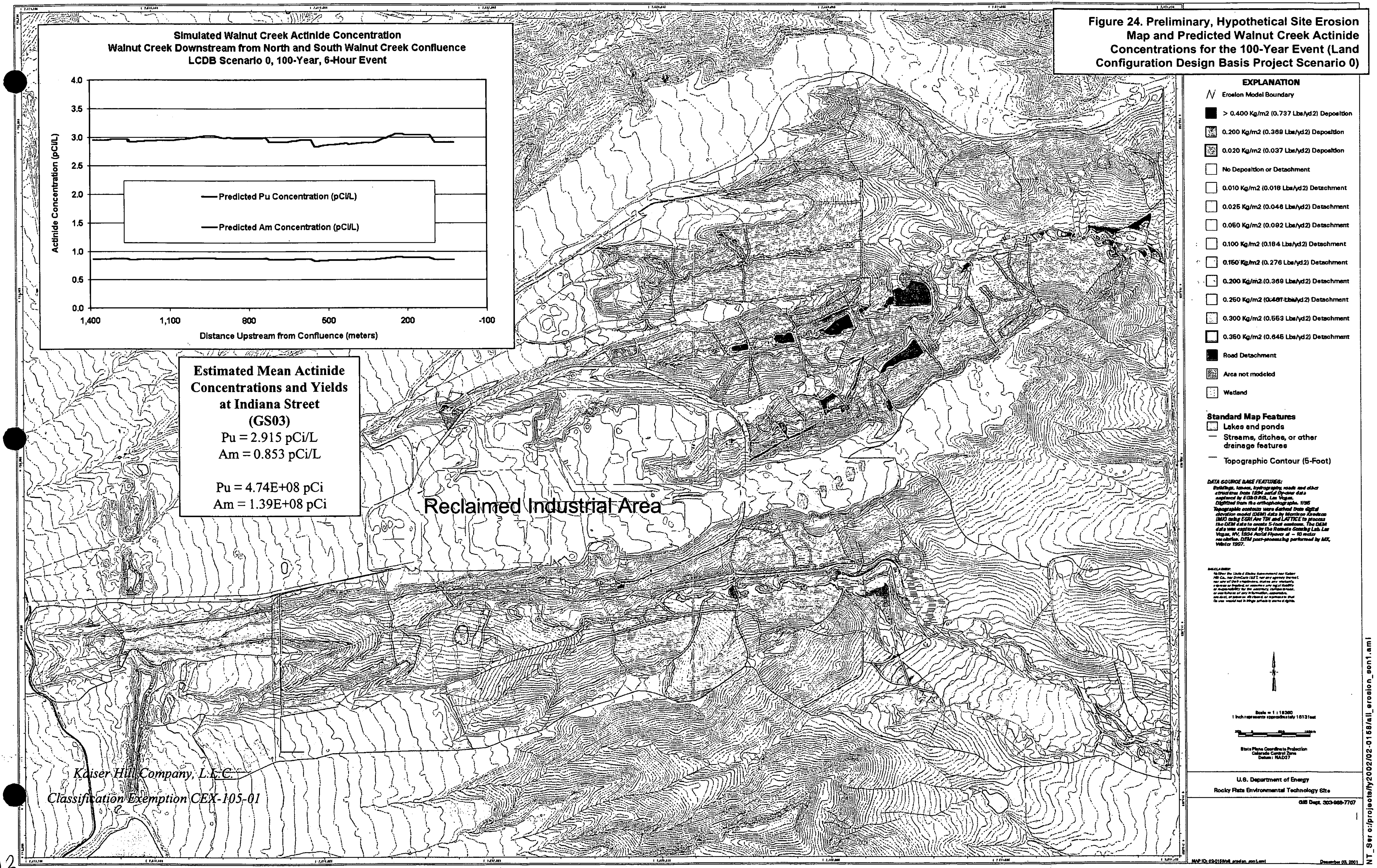
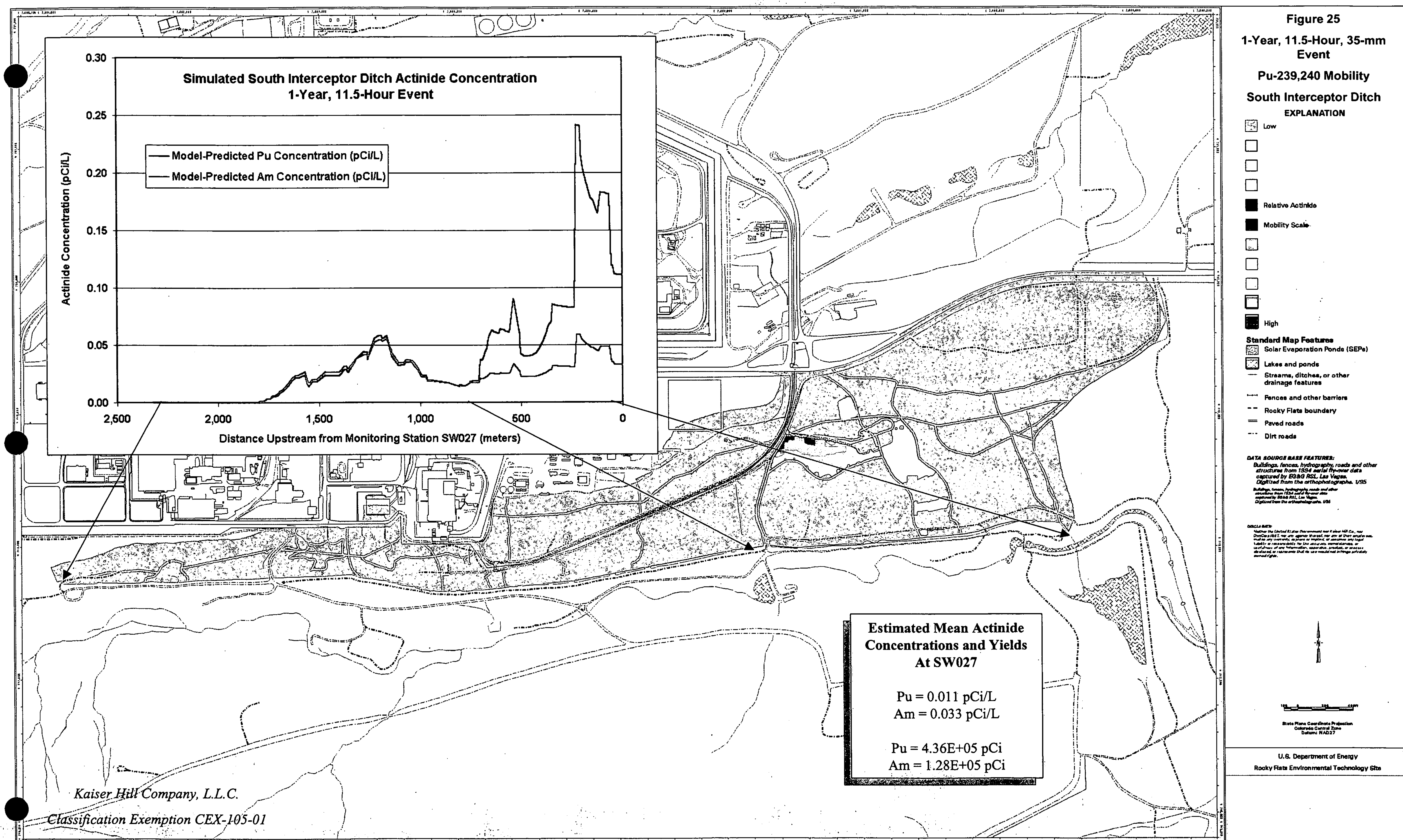
111

Figure 24. Preliminary, Hypothetical Site Erosion Map and Predicted Walnut Creek Actinide Concentrations for the 100-Year Event (Land Configuration Design Basis Project Scenario 0)



113



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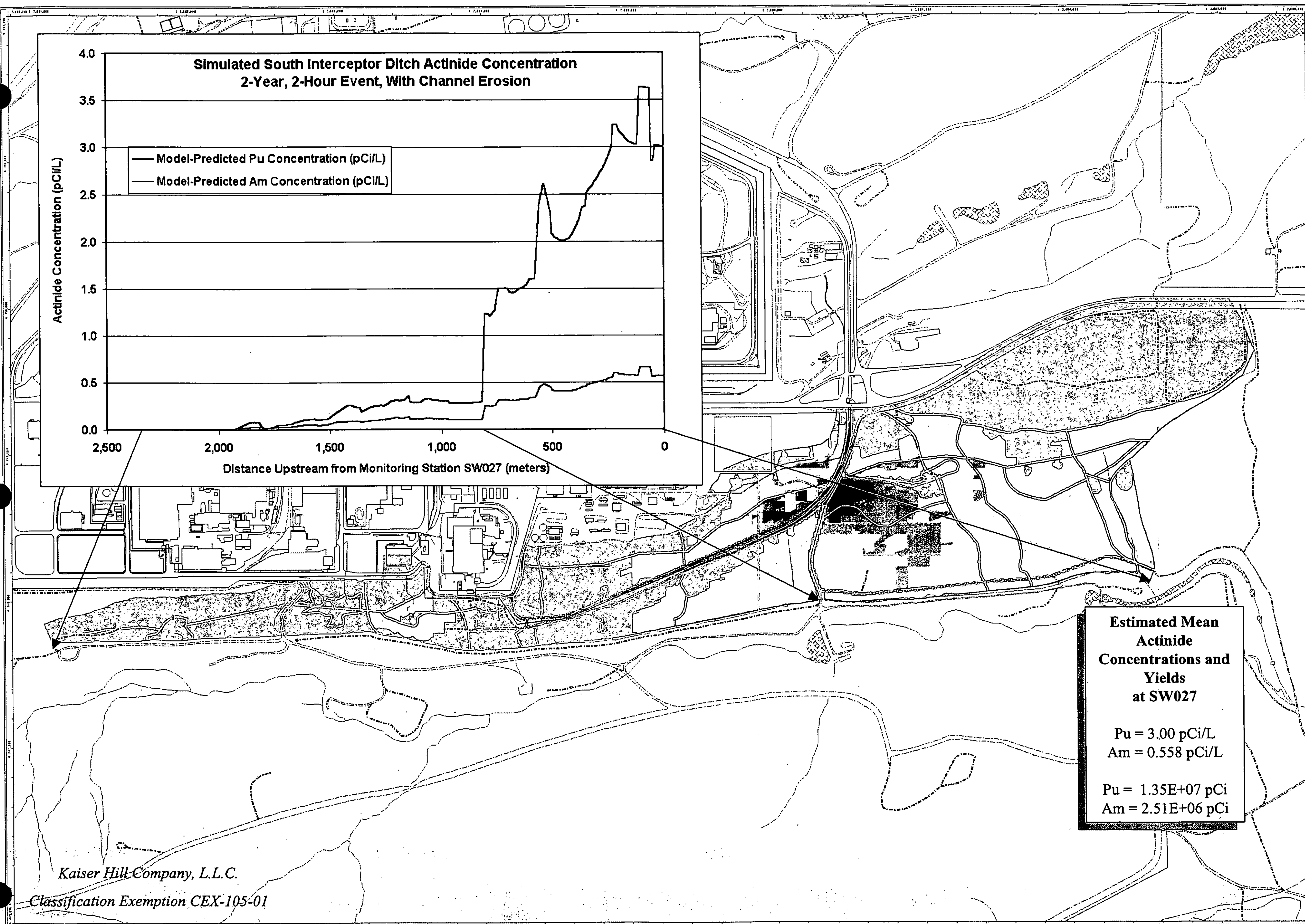

Figure 26

2-Year, 2-Hour, 31.5-mm Event

Pu-239,240 Mobility

South Interceptor Ditch

EXPLANATION

Low

Relative Actinide

Mobility Scale

High

Standard Map Features

Solar Evaporation Ponds (SEPs)

Lakes and ponds

Streams, ditches, or other drainage features

Fences and other barriers

Rocky Flats boundary

Paved roads

Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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115

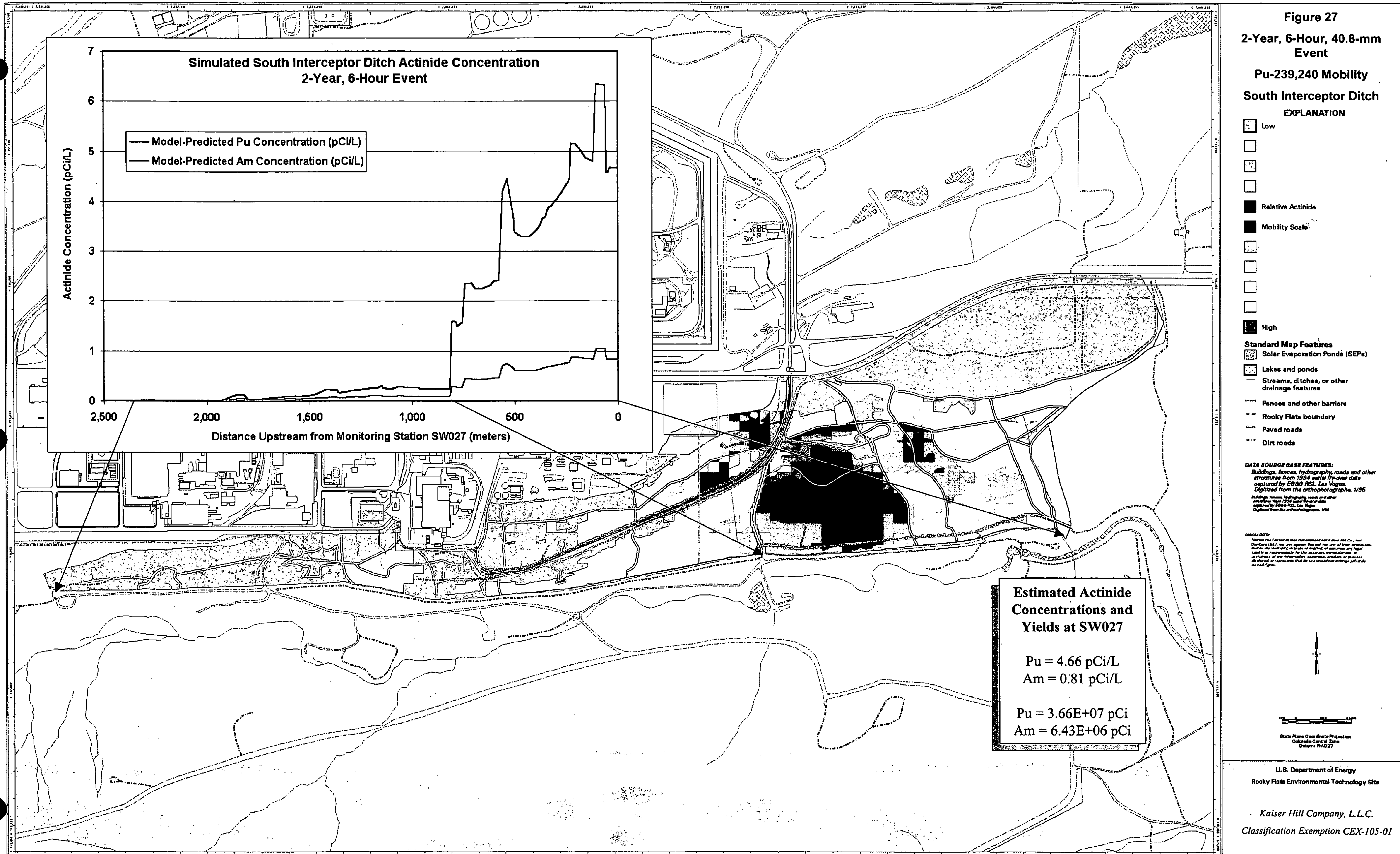

Figure 27
2-Year, 6-Hour, 40.8-mm Event
Pu-239,240 Mobility
South Interceptor Ditch
EXPLANATION
Low
Relative Actinide
Mobility Scale
High
Standard Map Features
Solar Evaporation Ponds (SEPs)
Lakes and ponds
Streams, ditches, or other drainage features
Fences and other barriers
Rocky Flats boundary
Paved roads
Dirt roads
DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95
State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27
U.S. Department of Energy
Rocky Flats Environmental Technology Site
Kaiser Hill Company, L.L.C.
Classification Exemption CEX-105-01
Simulated South Interceptor Ditch Actinide Concentration
2-Year, 6-Hour Event
Model-Predicted Pu Concentration (pCi/L)
Model-Predicted Am Concentration (pCi/L)
Actinide Concentration (pCi/L)
0
1
2
3
4
5
6
7
2,500
2,000
1,500
1,000
500
0
Distance Upstream from Monitoring Station SW027 (meters)
Estimated Actinide Concentrations and Yields at SW027
Pu = 4.66 pCi/L
Am = 0.81 pCi/L
Pu = 3.66E+07 pCi
Am = 6.43E+06 pCi

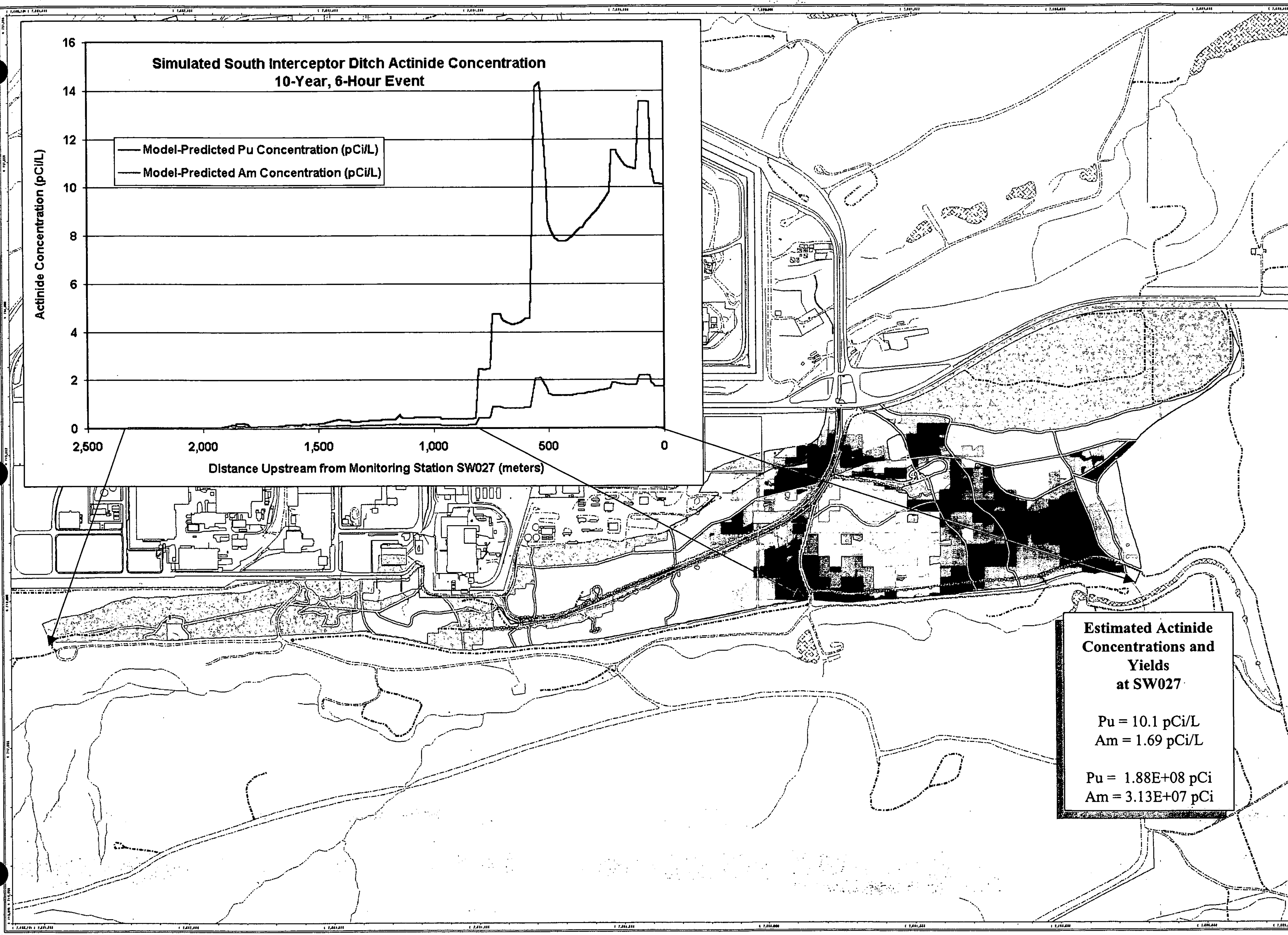

Figure 28
10-Year, 6-Hour,
62.3-mm Event
Pu-239,240 Mobility
South Interceptor Ditch

EXPLANATION

Low

Relative Actinide Mobility Scale

High

Standard Map Features

Solar Evaporation Ponds (SEPs)

Lakes and ponds

Streams, ditches, or other drainage features

Fences and other barriers

Rocky Flats boundary

Paved roads

Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
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NT_Sw d:/projects/fy2001/01-0843/eid_pu_mob_m2_10yr.aml

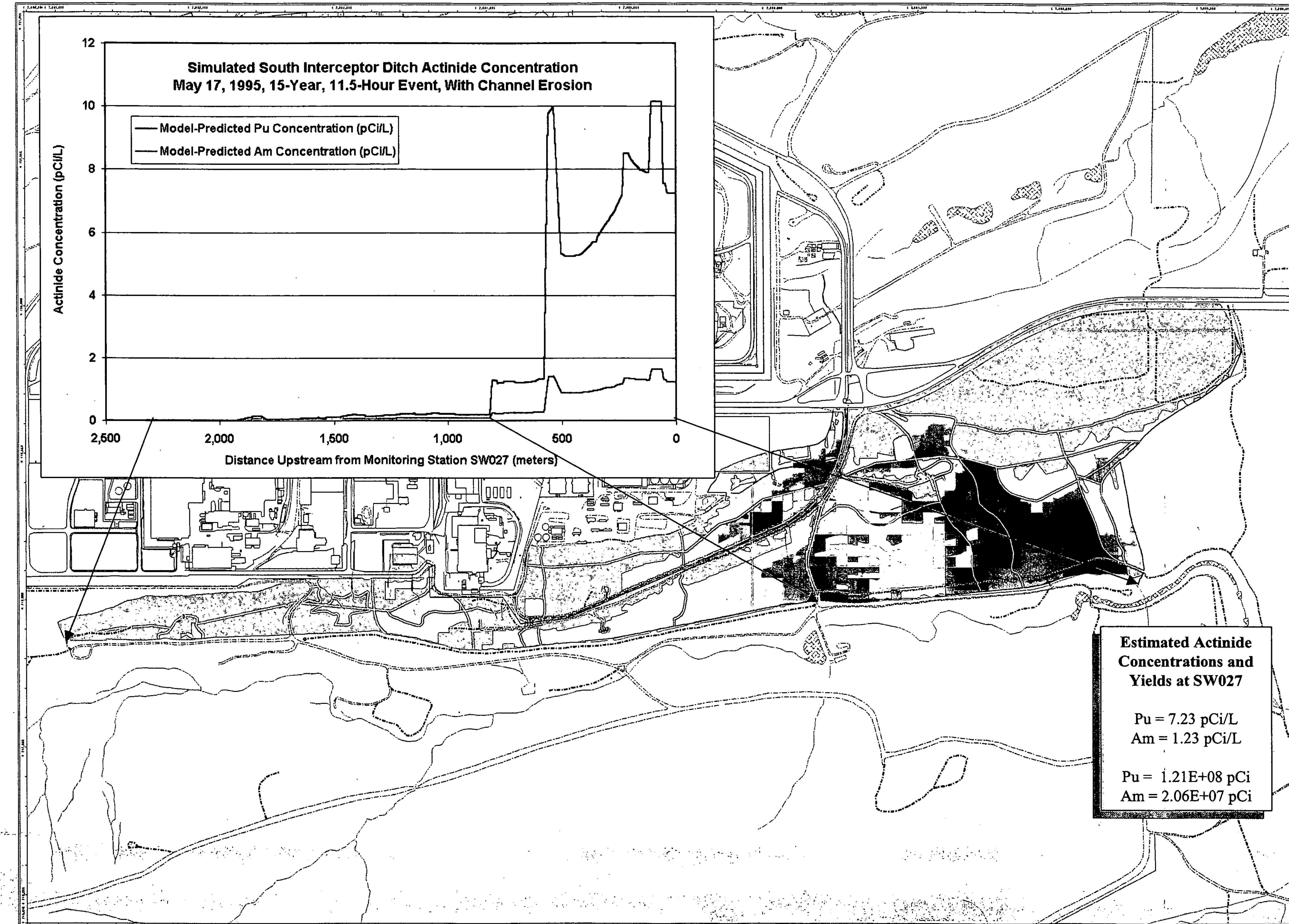
117

Figure 29

May 17, 1995 Event

Pu-239,240 Mobility

South Interceptor Ditch



EXPLANATION

Low

Relative Actinide

Mobility Scale

High

Standard Map Features

Solar Evaporation Ponds (SEPs)

Lakes and ponds

Streams, ditches, or other drainage features

Fences and other barriers

Rocky Flats boundary

Paved roads

Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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NT-SYr d:/projects/fy2001/01-0847/sid_pu_mob_m2_may17.aml

118

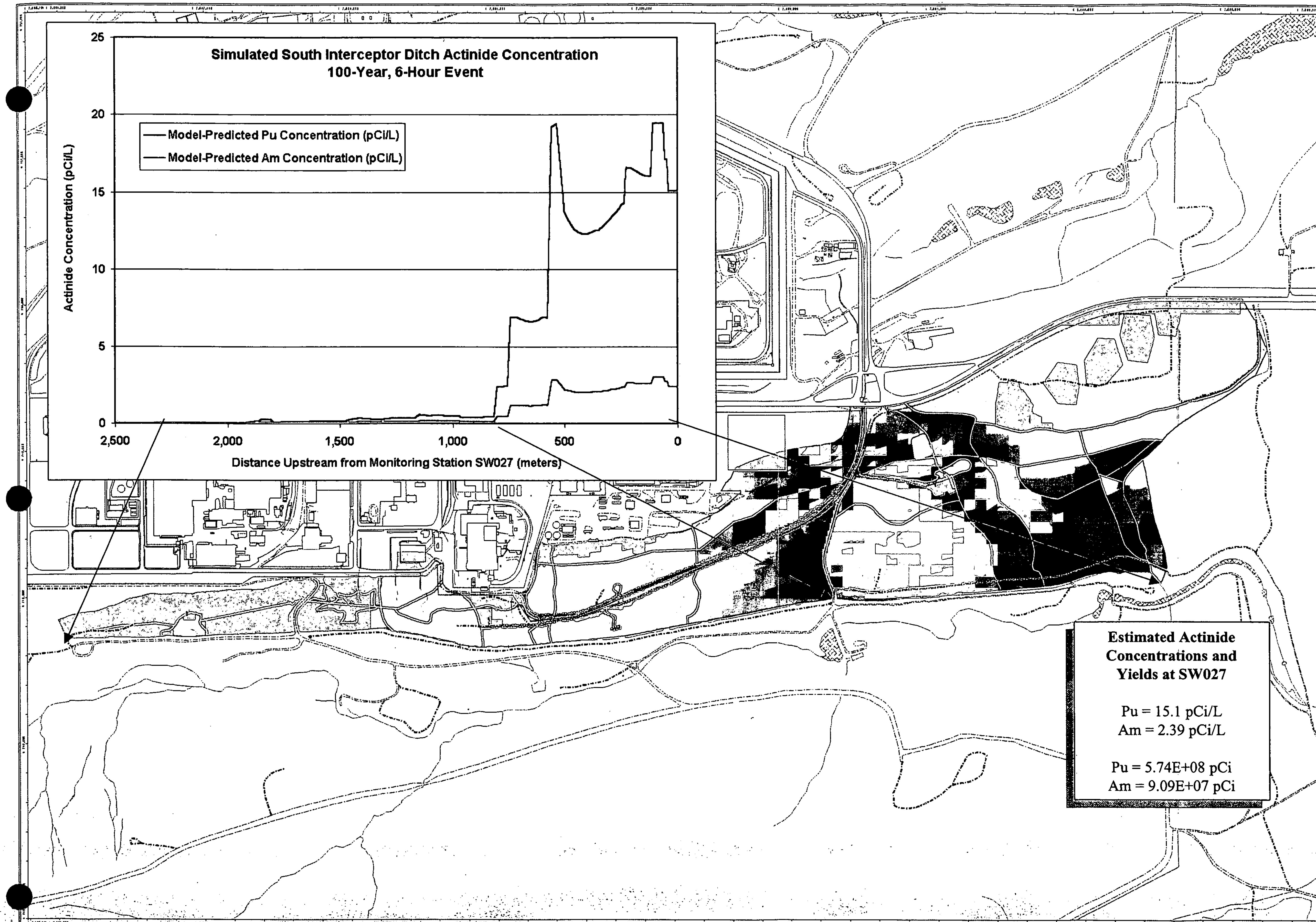

Figure 30

100-Year, 6-Hour, 97.1-mm Event

Pu-239,240 Mobility

South Interceptor Ditch

EXPLANATION

Low

Relative Actinide

Mobility Scale

High

Standard Map Features

Solar Evaporation Ponds (SEPs)

Lakes and ponds

Streams, ditches, or other drainage features

Fences and other barriers

Rocky Flats boundary

Paved roads

Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95
Data Source:
Mobility data - Approved by Win Chromec (RMRS, 303-966-4535).

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy

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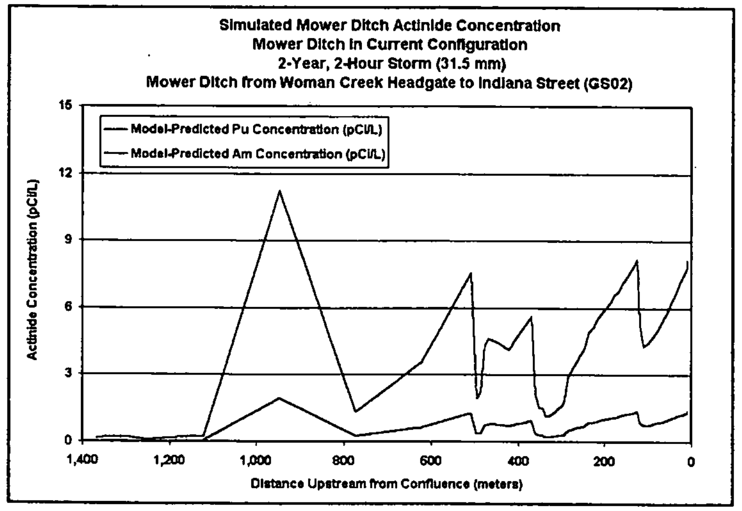
NT Svr d:/projects/fy2001/01-0842/sid pu mob m2 100yr.aml

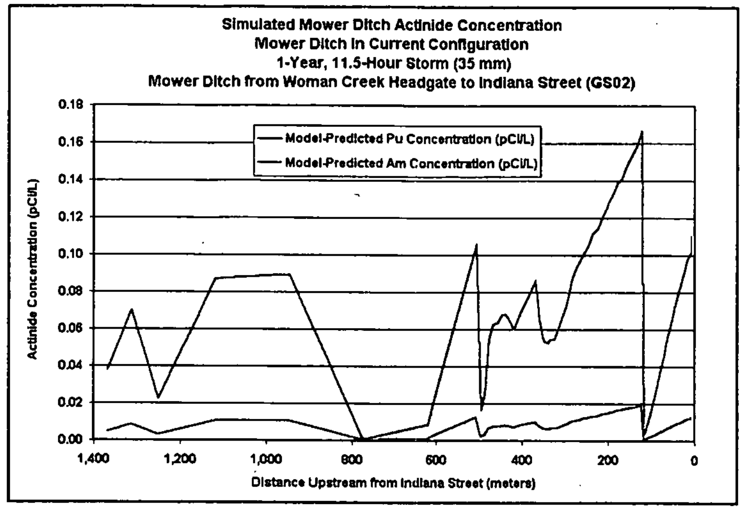
119

Figure 31. Mower Ditch - Model-predicted Surface Water Pu and Am Concentrations for 6 Storm Events

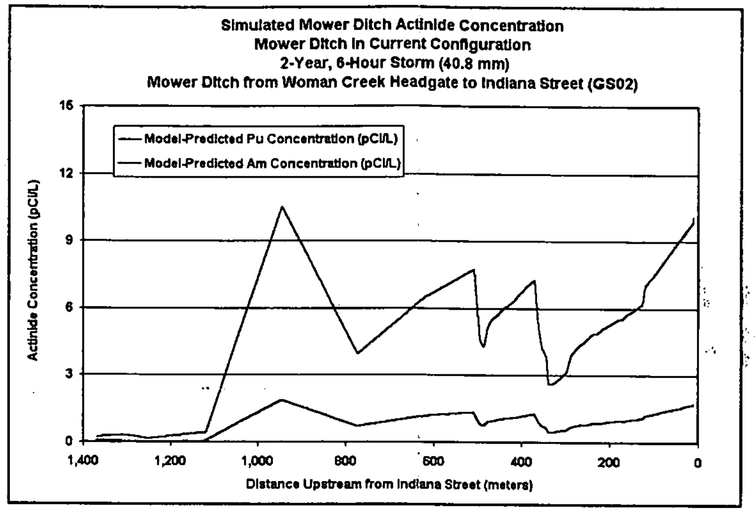
2-Year, 2-Hour Storm (31.5 mm)



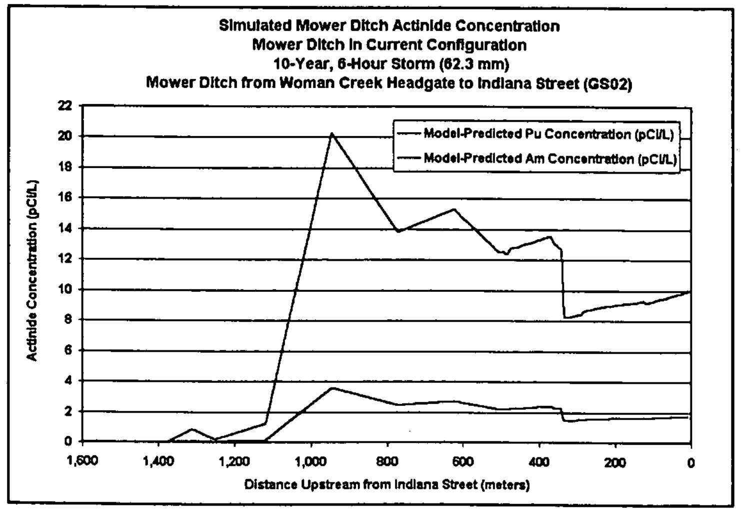
1-Year, 11.5-Hour Storm (35 mm)



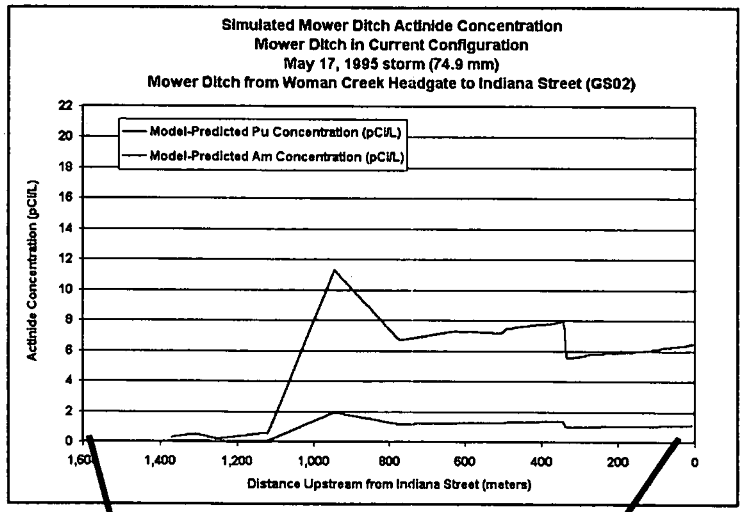
2-Year, 6-Hour Storm (40.8 mm)



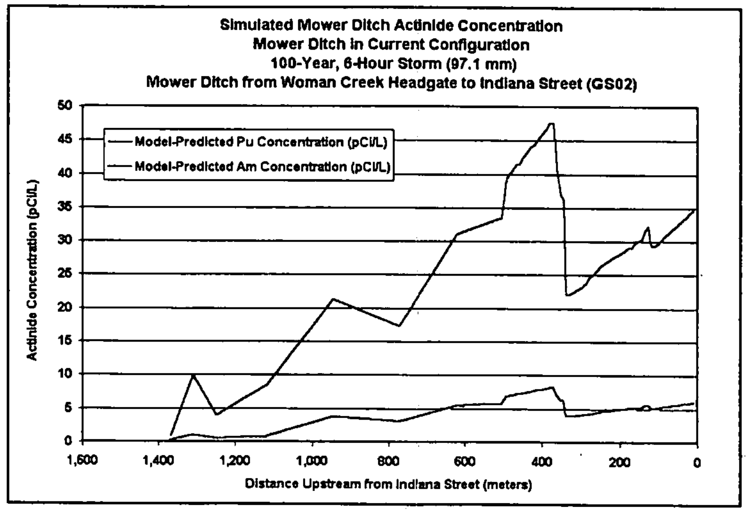
10-Year, 6-Hour Storm (62.3 mm)

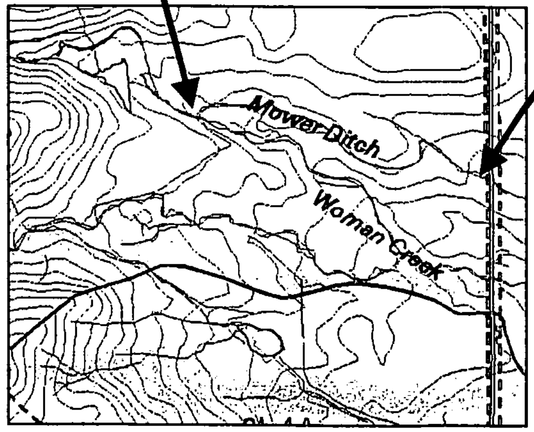


May 17, 1995 Storm (74.9 mm)



100-Year, 6-Hour Storm (97.1 mm)



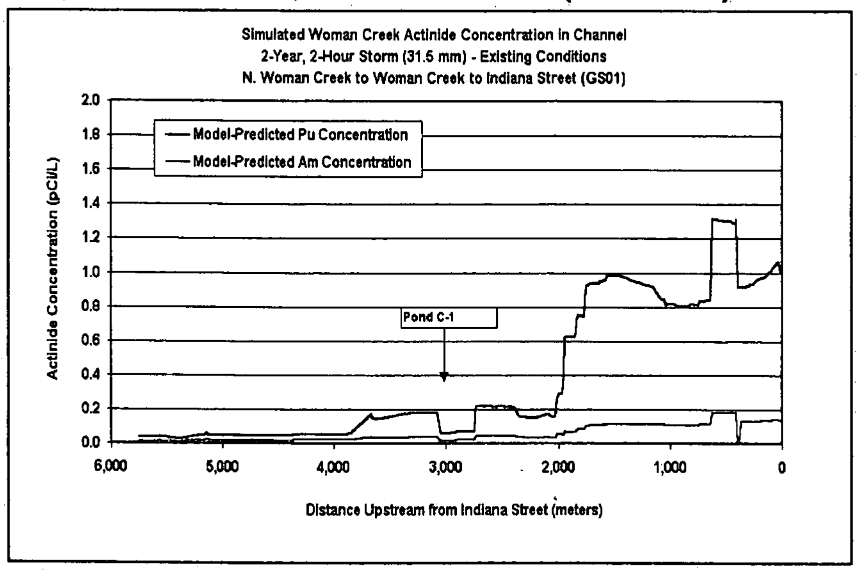


Mower Ditch Location Reference

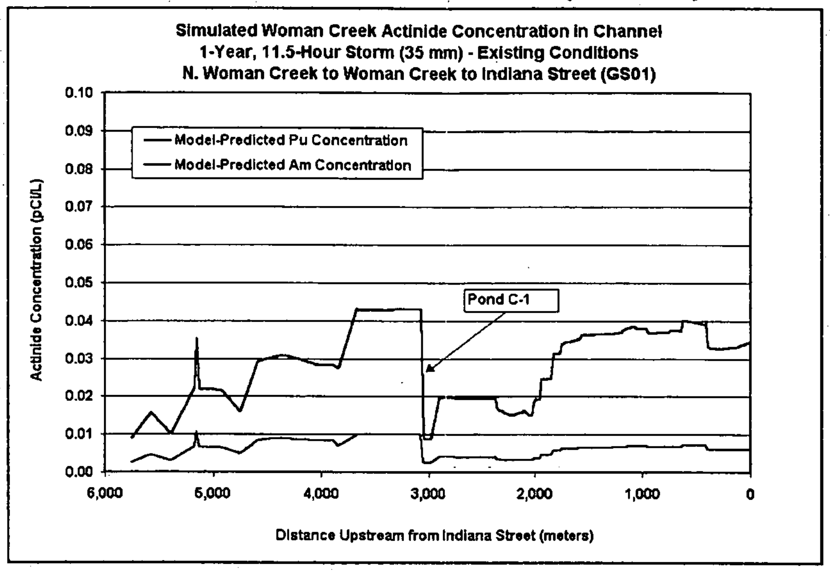
Mower Ditch Scenarios	Estimated Pu Yield (pCi)	Estimated Am Yield (pCi)
2-Year 2-Hour (31.5mm)	6.99E+06	1.15E+06
1-Year 11.5-Hour (35mm)	1.08E+05	1.25E+04
2-Year 6-Hour (40.8mm)	2.22E+07	3.75E+06
10-Year 6-Hour (62.3mm)	8.54E+07	1.46E+07
5/17/2001 (74.9mm)	8.72E+07	1.45E+07
100-Year 6-Hour (97.1mm)	9.28E+08	1.58E+08

Figure 32. Woman Creek - Model-predicted Surface Water Pu and Am Concentrations for 6 Storm Events

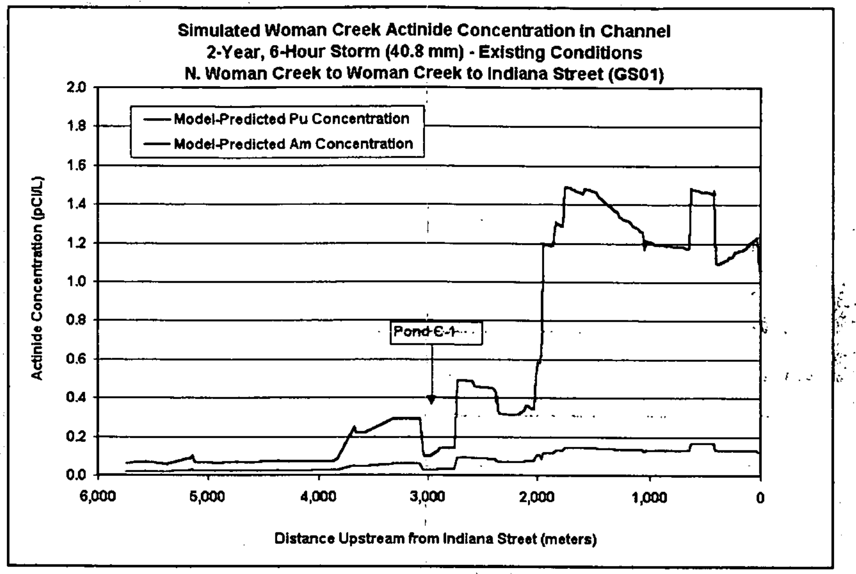
2-Year, 2-Hour Storm (31.5 mm)



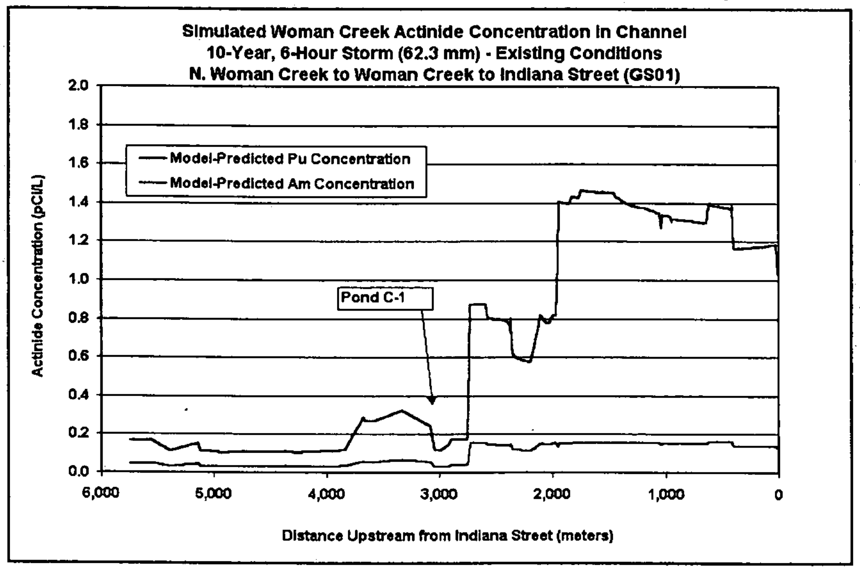
1-Year, 11.5-Hour Storm (35 mm)



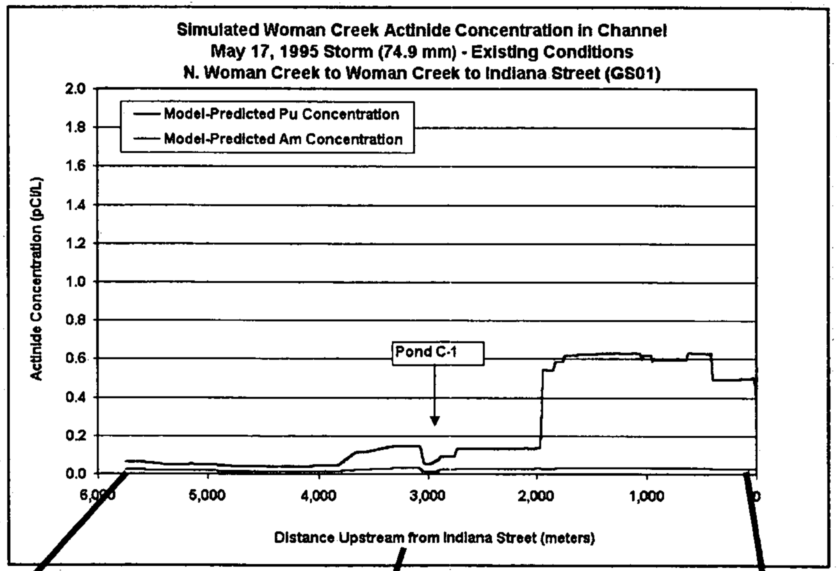
2-Year, 6-Hour Storm (40.8 mm)



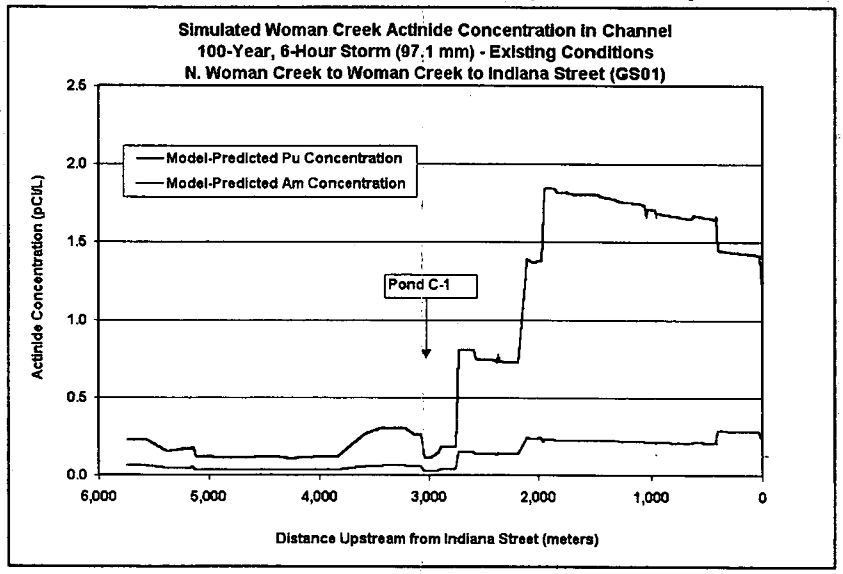
10-Year, 6-Hour Storm (62.3 mm)



May 17, 1995 Storm (74.9 mm)



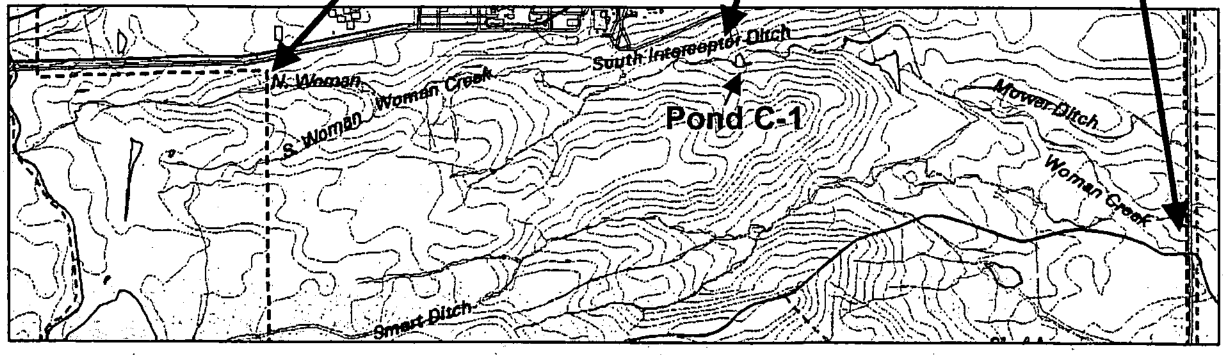
100-Year, 6-Hour Storm (97.1 mm)



Kaiser Hill Company, L.L.C.

Classification Exemption CEX-105-01

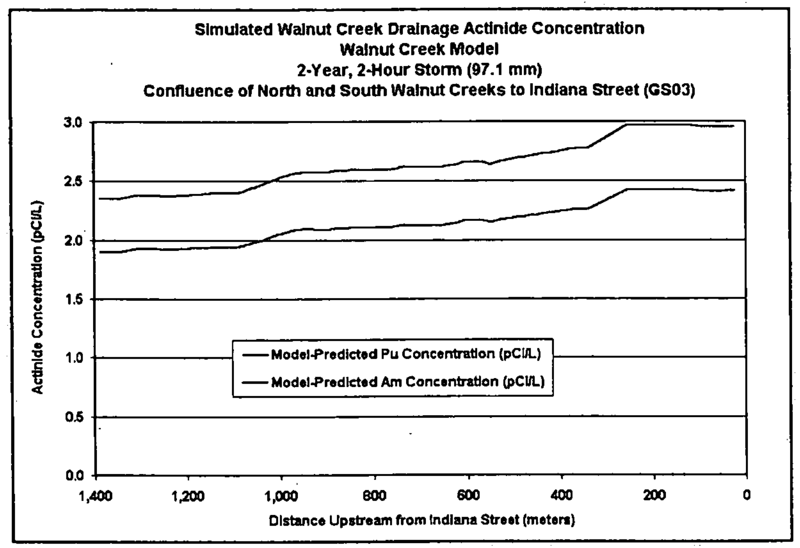
Woman Creek Location Reference



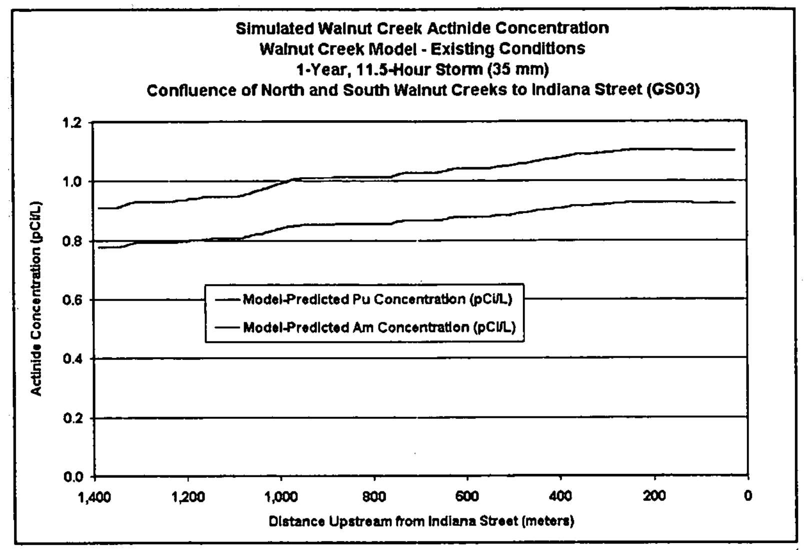
Woman Creek Scenarios	Estimated Pu Yield (pCi)	Estimated Am Yield (pCi)
2-Year 2-Hour (31.5mm)	8.23E+06	1.09E+06
1-Year 11.5-Hour (35mm)	4.97E+05	8.46E+04
2-Year 6-Hour (40.8mm)	1.41E+07	1.53E+06
10-Year 6-Hour (62.3mm)	5.08E+07	6.04E+06
5/17/2001 (74.9mm)	2.87E+07	1.81E+06
100-Year 6-Hour (97.1mm)	1.80E+08	3.38E+07

Figure 33. Lower Walnut Creek - Model-Predicted Surface Water Pu and Am Concentrations for 6 Storm Events

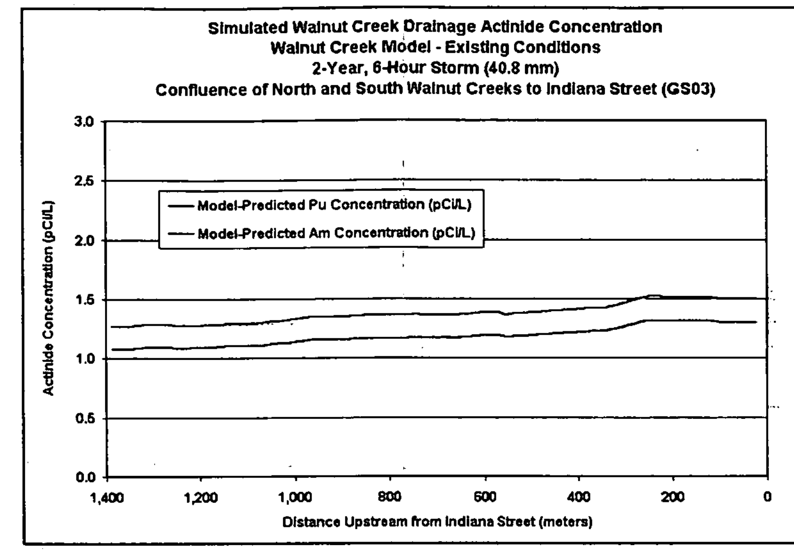
2-Year, 2-Hour Storm (31.5 mm)



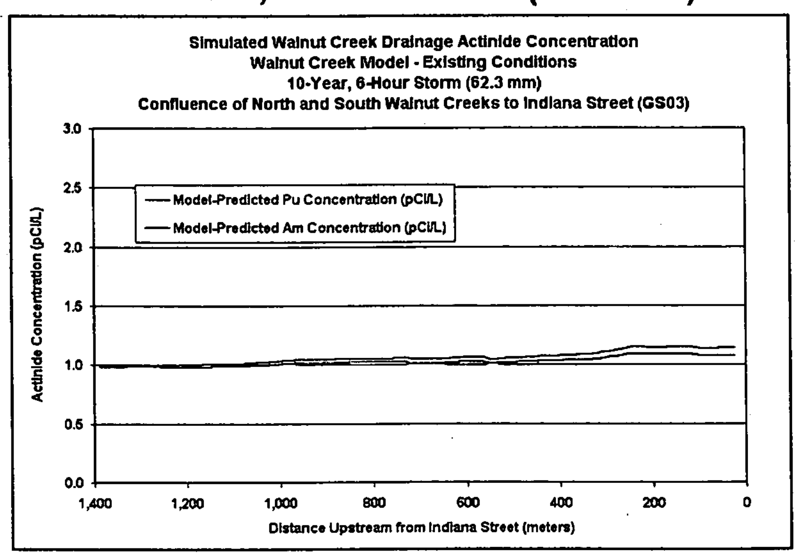
1-Year, 11.5-Hour Storm (35 mm)



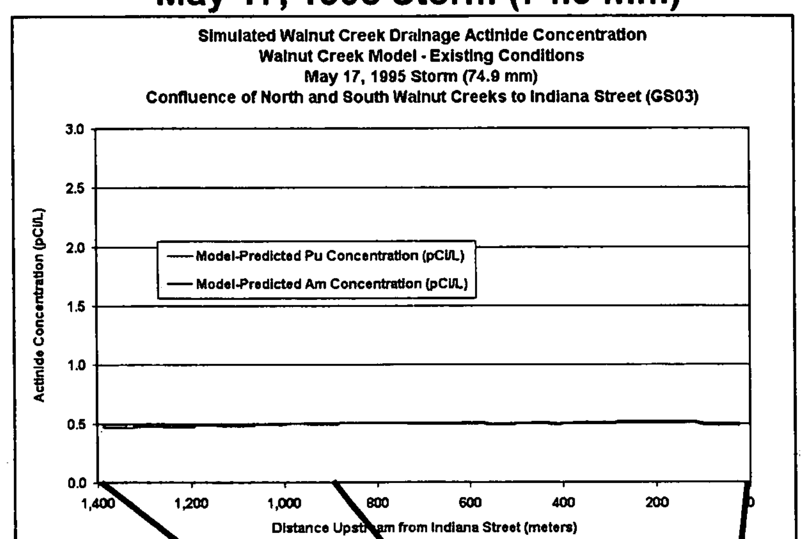
2-Year, 6-Hour Storm (40.8 mm)



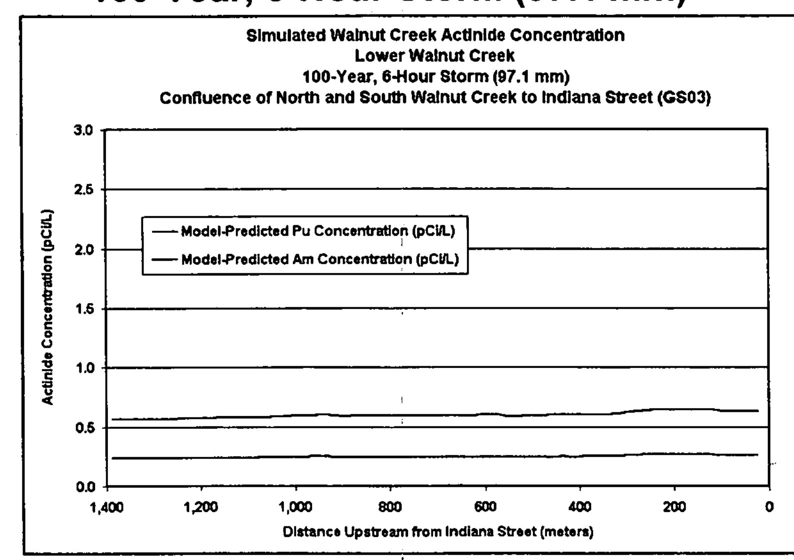
10-Year, 6-Hour Storm (62.3 mm)

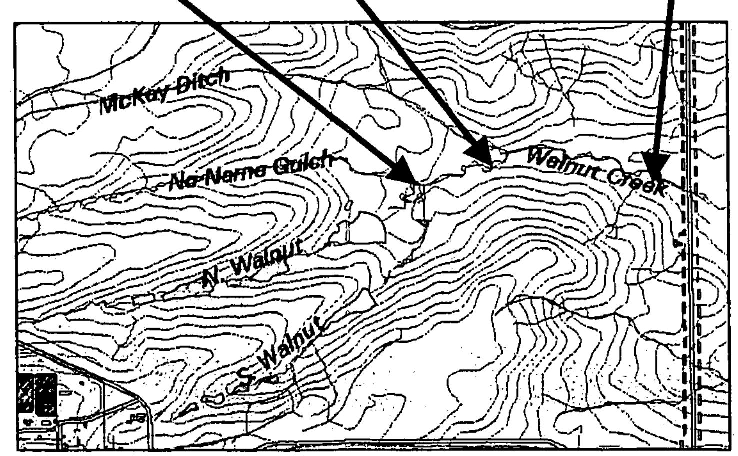


May 17, 1995 Storm (74.9 mm)



100-Year, 6-Hour Storm (97.1 mm)



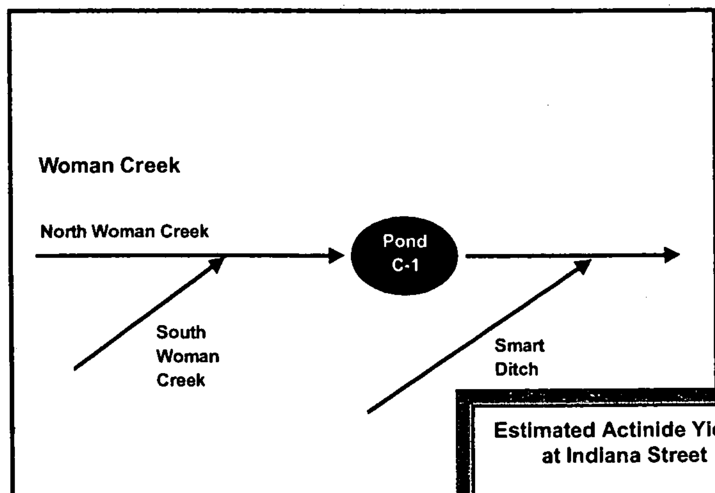


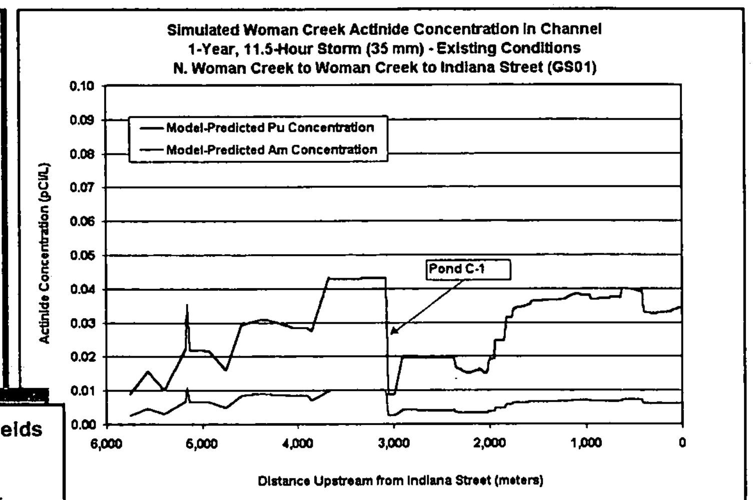
Lower Walnut Creek Location Reference

Walnut Creek Scenarios	Estimated Pu Yield (pCi)	Estimated Am Yield (pCi)
2-Year 2-Hour (31.5mm)	1.04E+08	1.27E+08
1-Year 11.5-Hour (35mm)	4.44E+07	5.28E+07
2-Year 6-Hour (40.8mm)	8.01E+07	9.19E+07
10-Year 6-Hour (62.3mm)	1.01E+08	9.46E+07
5/17/2001 (74.9mm)	8.01E+07	7.66E+07
100-Year 6-Hour (97.1mm)	1.60E+08	6.43E+07

Figure 34. Woman Creek - 3 Configuration Alternatives Model-predicted Pu and Am Surface Water Concentrations in Woman Creek - 1-Year, 11.5 hour Storm (35-mm)

Woman Creek: Current Configuration

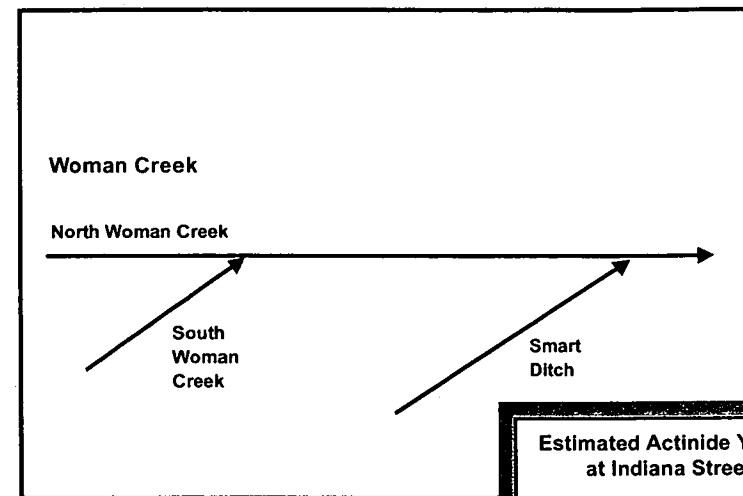


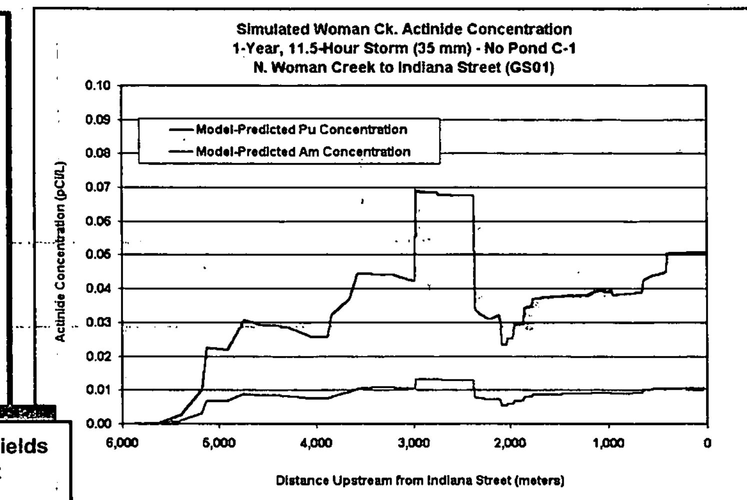


Estimated Actinide Yields at Indiana Street

Pu = 4.97E+05 pCi
Am = 8.46E+04 pCi

Woman Creek: Pond C-1 Removed

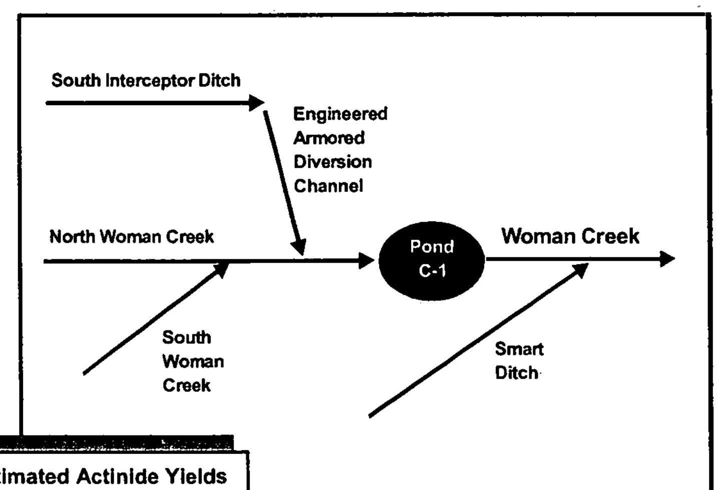


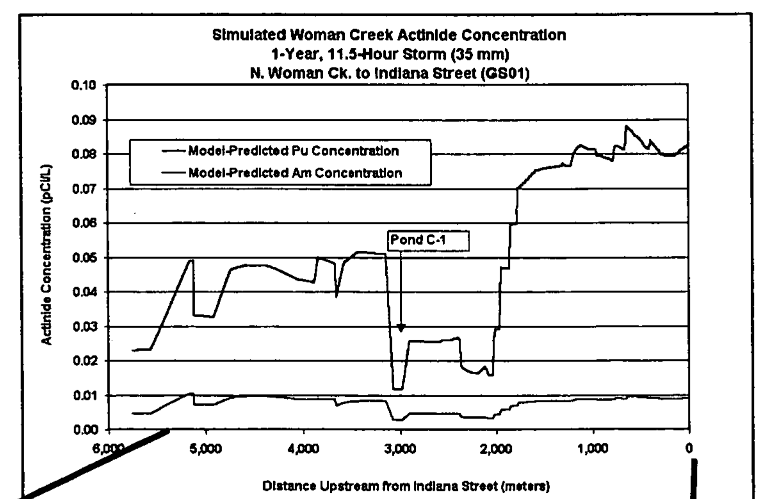


Estimated Actinide Yields at Indiana Street

Pu = 7.36E+05 pCi
Am = 1.47E+05 pCi

Woman Creek: South Interceptor Ditch Routed Into Woman Creek





Estimated Actinide Yields at Indiana Street

Pu = 1.44E+06 pCi
Am = 1.51E+05 pCi

Woman Creek Location Reference

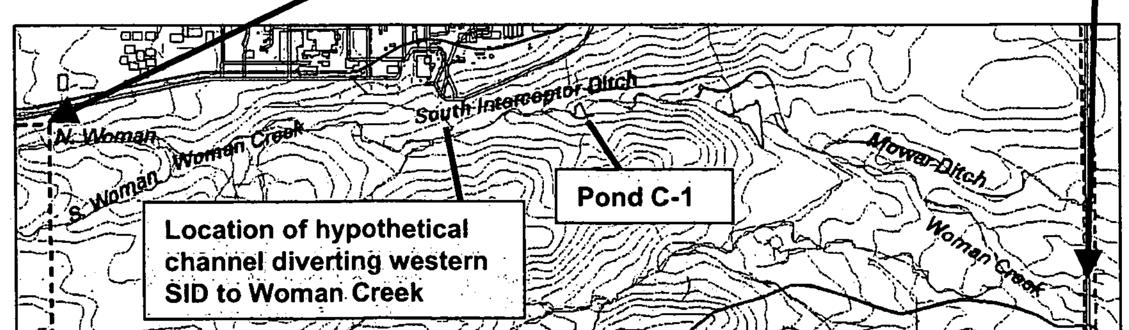
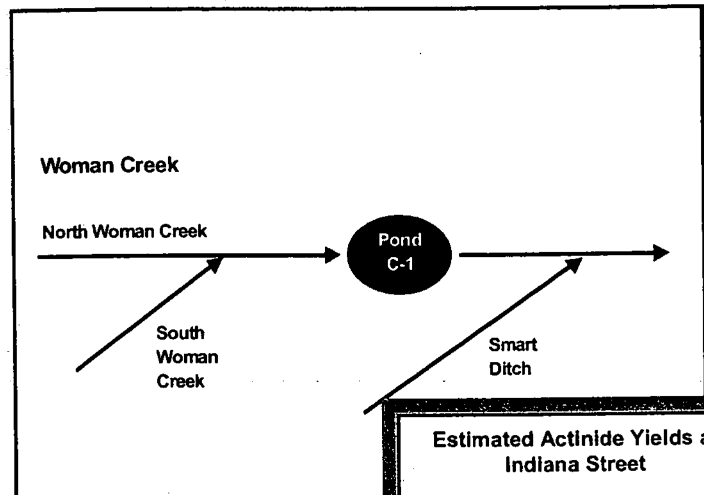
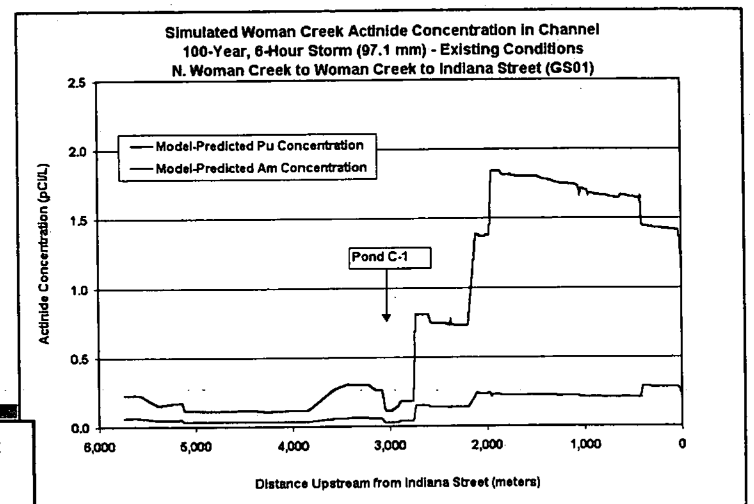


Figure 35. Woman Creek - 3 Configuration Alternatives Model-predicted Pu and Am Surface Water Concentrations in Woman Creek 100-Year, 6-Hour Storm (97.1-mm)

Woman Creek: Current Configuration

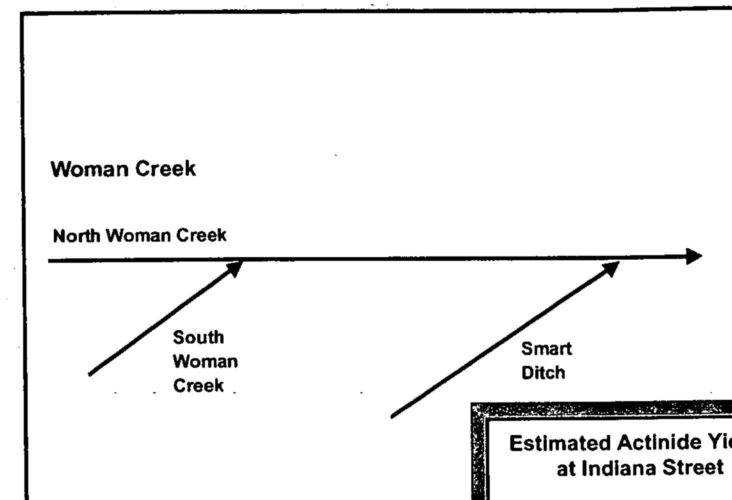


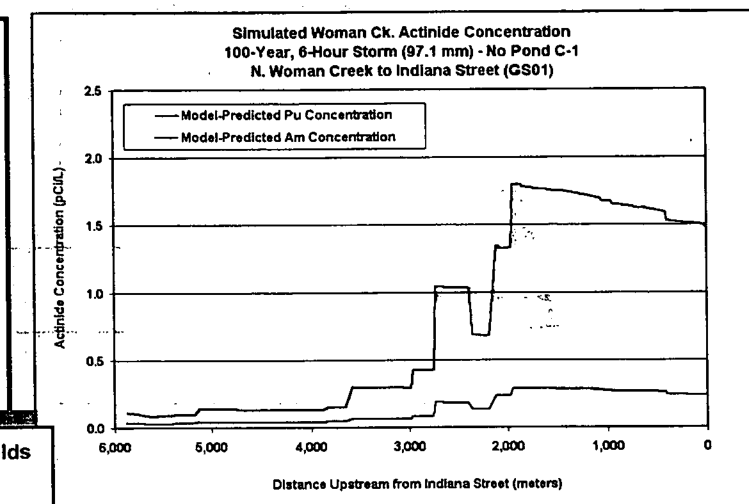


Estimated Actinide Yields at Indiana Street

Pu = 1.80E+08 pCi
Am = 3.38E+07 pCi

Woman Creek: Pond C-1 Removed

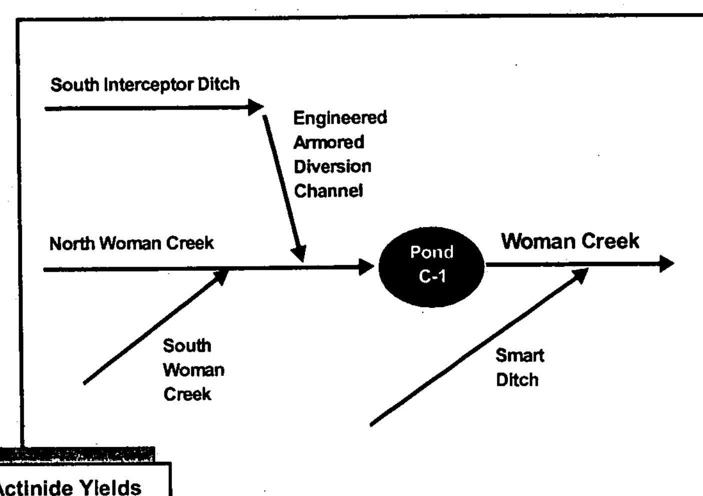


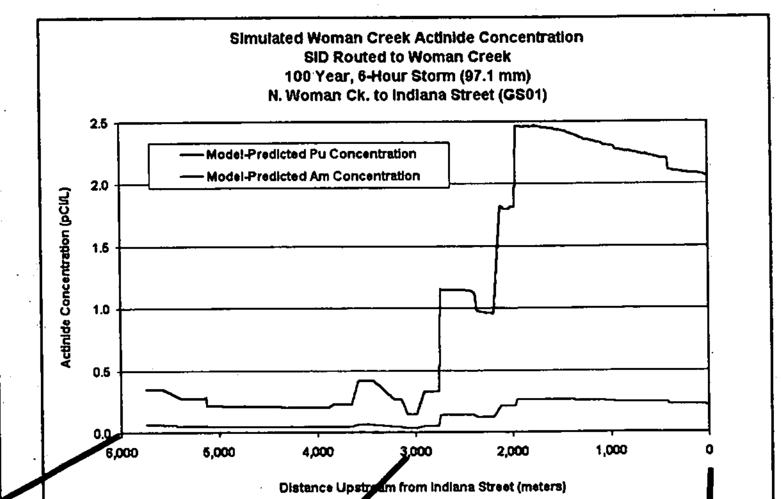


Estimated Actinide Yields at Indiana Street

Pu = 2.17E+08 pCi
Am = 3.32E+07 pCi

Woman Creek: South Interceptor Ditch Routed Into Woman Creek





Estimated Actinide Yields at Indiana Street

Pu = 3.31E+08 pCi
Am = 3.41E+07 pCi

Woman Creek Location Reference

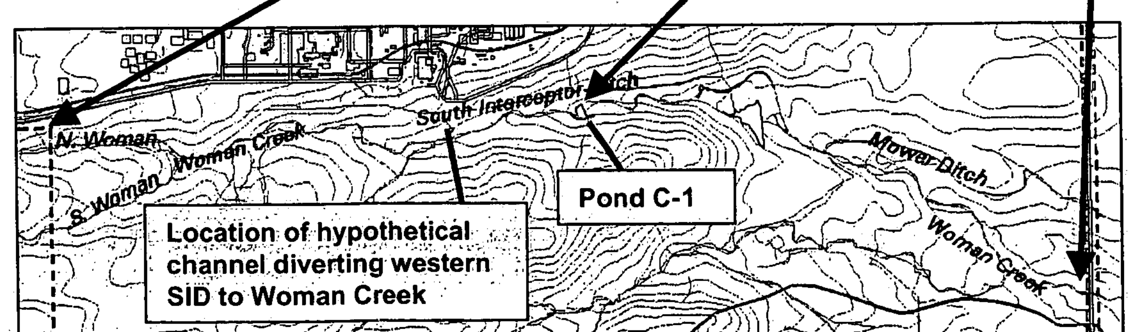


Figure 36. Comparison of Simulated Actinide Concentrations for Truncated SID

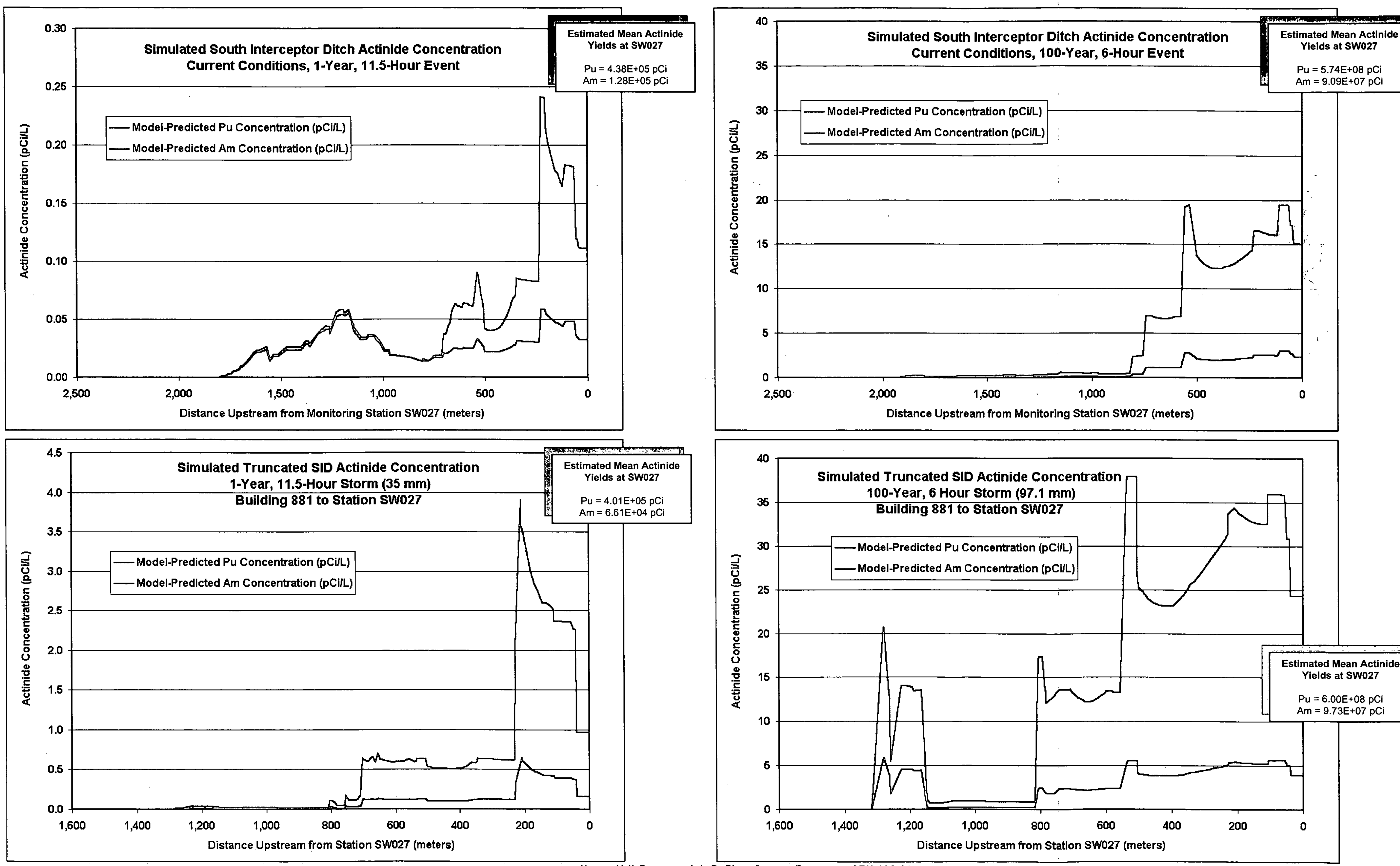
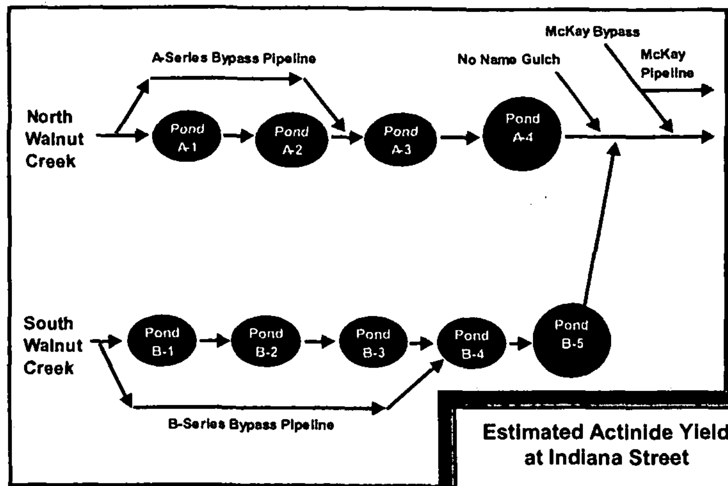
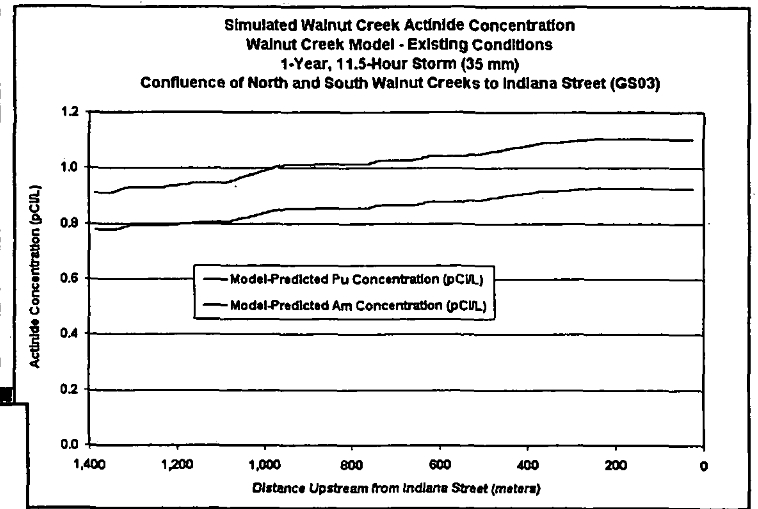


Figure 37. Walnut Creek - 4 Pond Configuration Alternatives Model-predicted Pu and Am Surface Water Concentrations in Lower Walnut Creek - 1-Year, 11.5 hour Storm (35-mm)

Walnut Creek: Current Pond Configuration

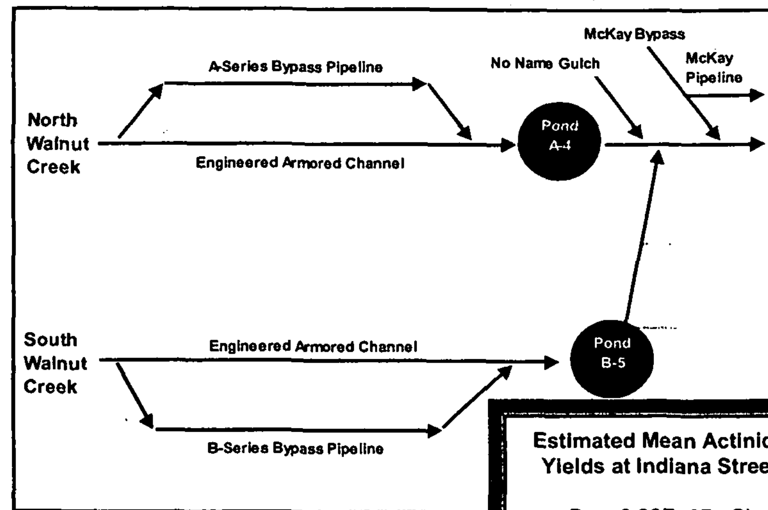


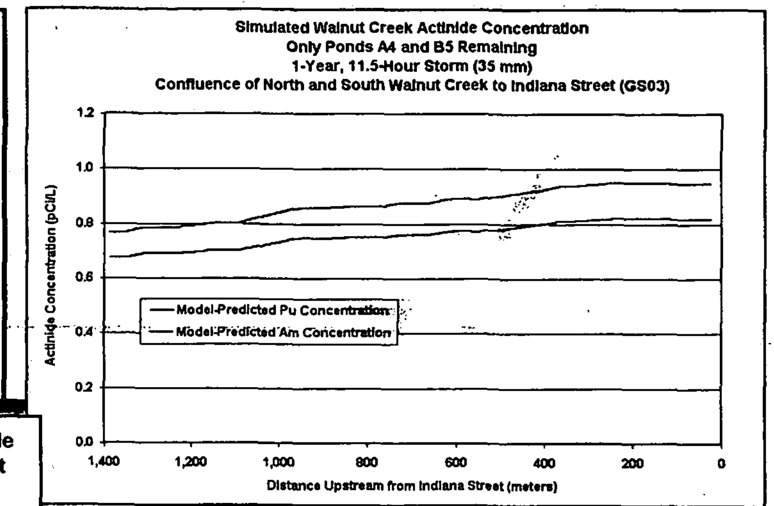


Estimated Actinide Yield at Indiana Street

Pu = 4.44E+07 pCi
Am = 5.28E+07 pCi

Walnut Creek: Only Pond A-4 and B-5 Remain

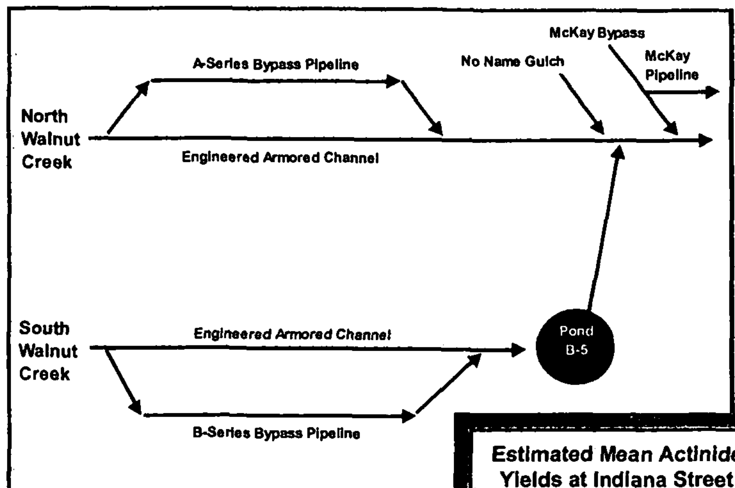


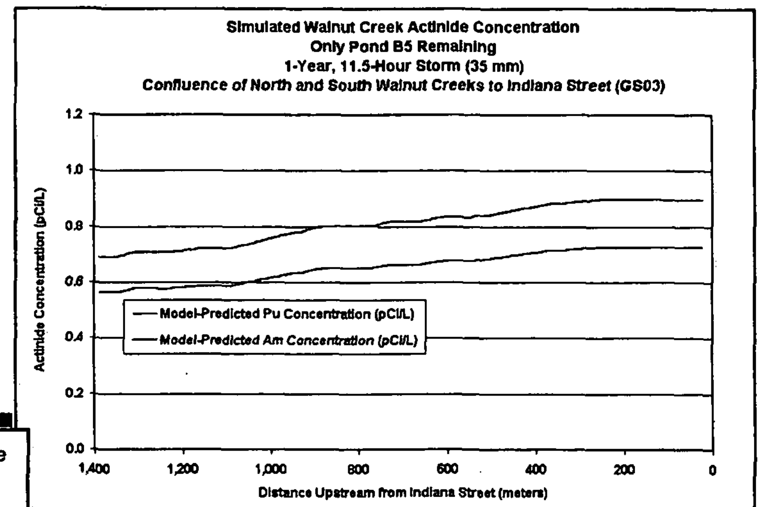


Estimated Mean Actinide Yields at Indiana Street

Pu = 3.92E+07 pCi
Am = 4.54E+07 pCi

Walnut Creek: Only Pond B-5 Remains

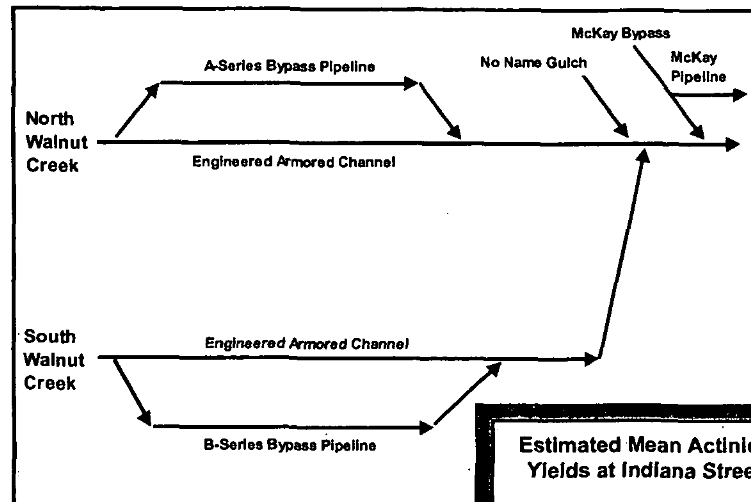


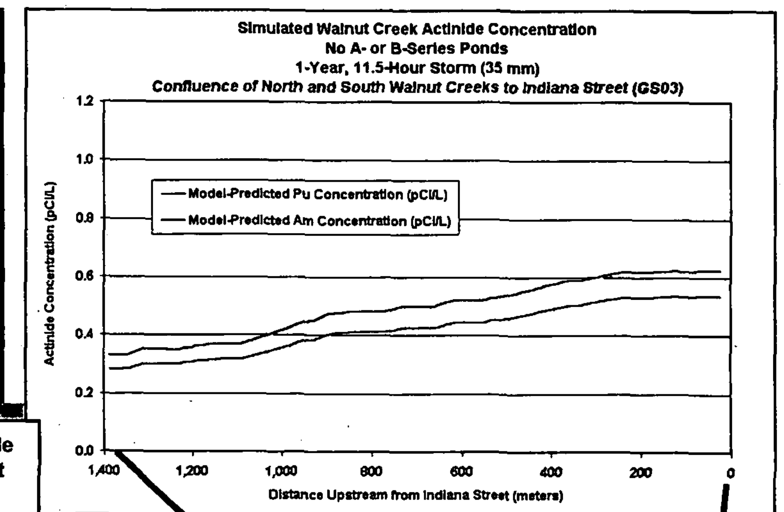


Estimated Mean Actinide Yields at Indiana Street

Pu = 3.47E+07 pCi
Am = 4.28E+07 pCi

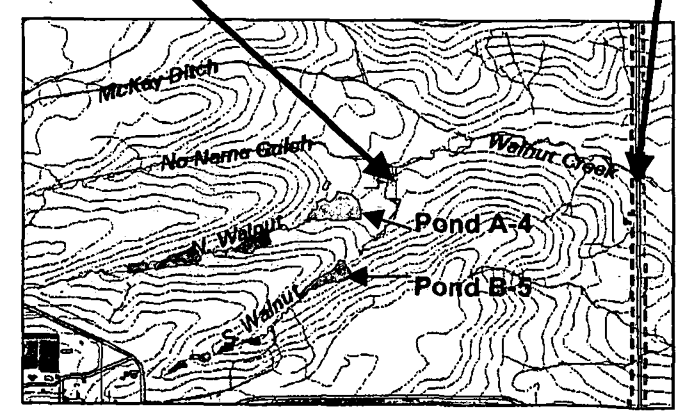
Walnut Creek: No Ponds Remain





Estimated Mean Actinide Yields at Indiana Street

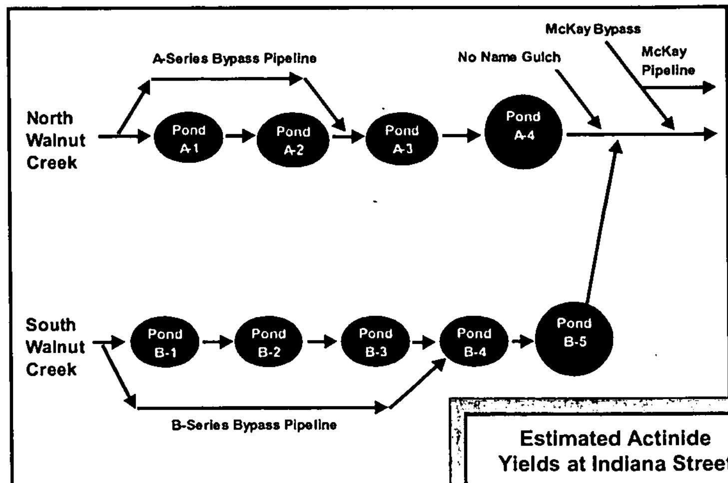
Pu = 2.56E+07 pCi
Am =2.97E+07 pCi

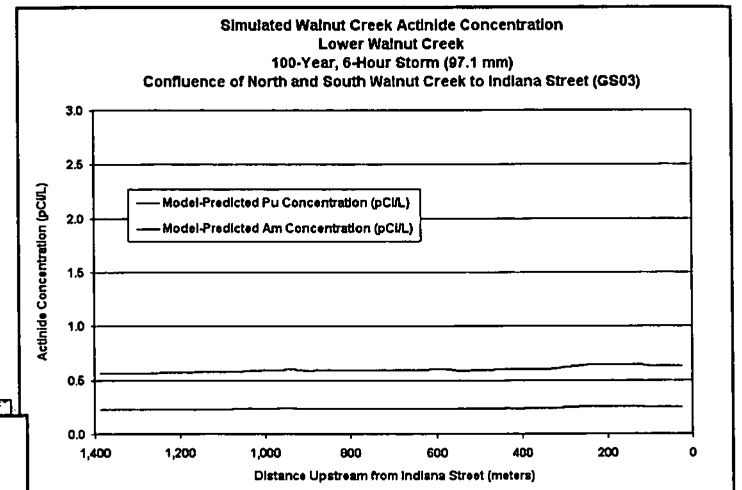


Lower Walnut Creek Location Reference

Figure 38. Walnut Creek - 4 Pond Configuration Alternatives Model-predicted Pu and Am Surface Water Concentrations in Lower Walnut Creek - 100-Year, 6-Hour Storm (97.1-mm)

Walnut Creek: Current Pond Configuration

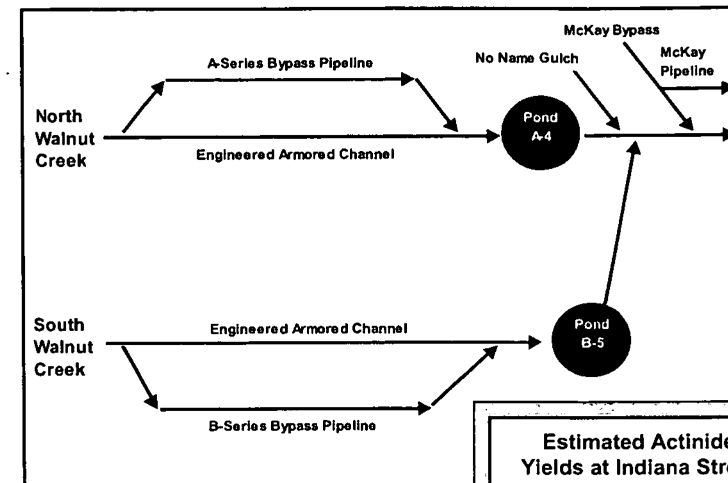


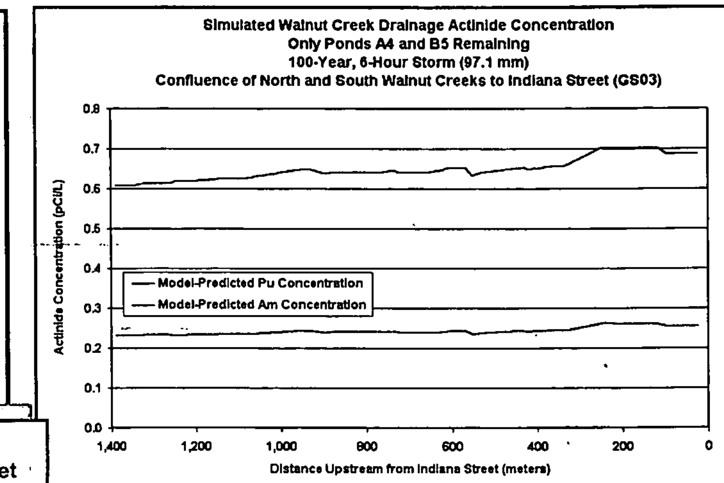


Estimated Actinide Yields at Indiana Street

Pu = 1.60E+08 pCi
Am = 6.43E+07 pCi

Walnut Creek: Only Pond A-4 and B-5 Remain

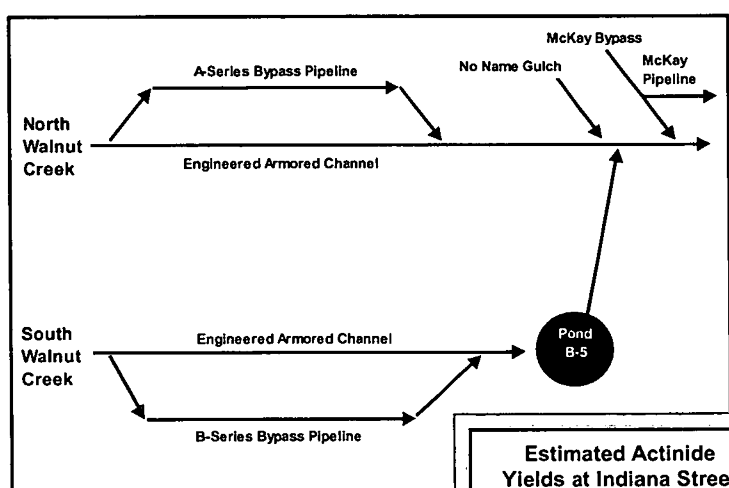


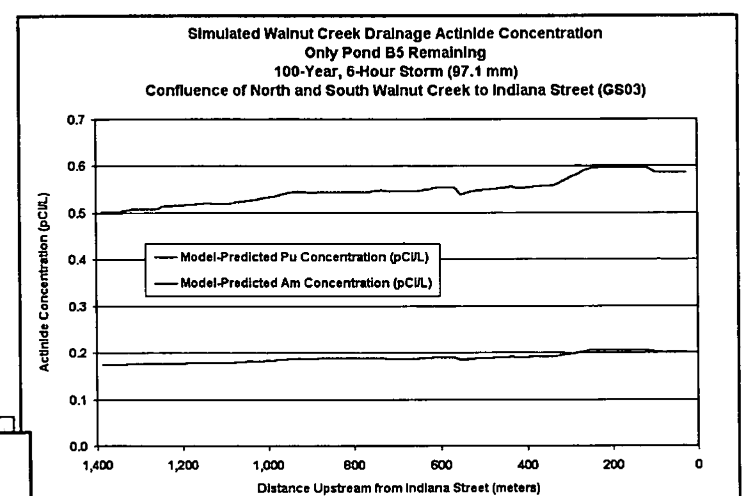


Estimated Actinide Yields at Indiana Street

Pu = 1.75E+08 pCi
Am = 6.52E+07 pCi

Walnut Creek: Only Pond B-5 Remains

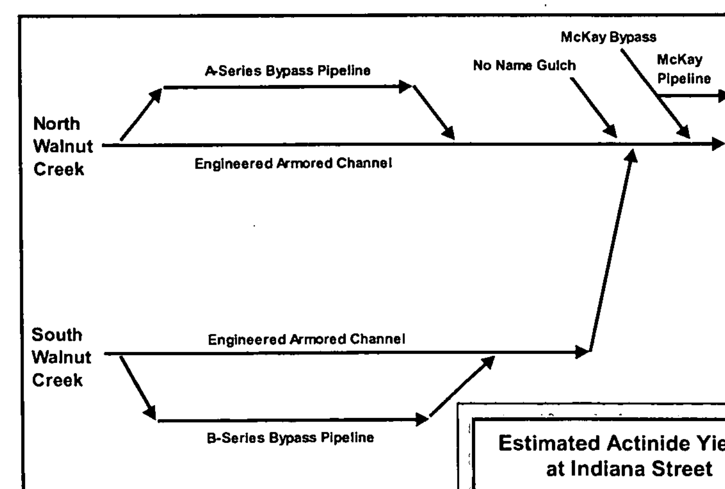


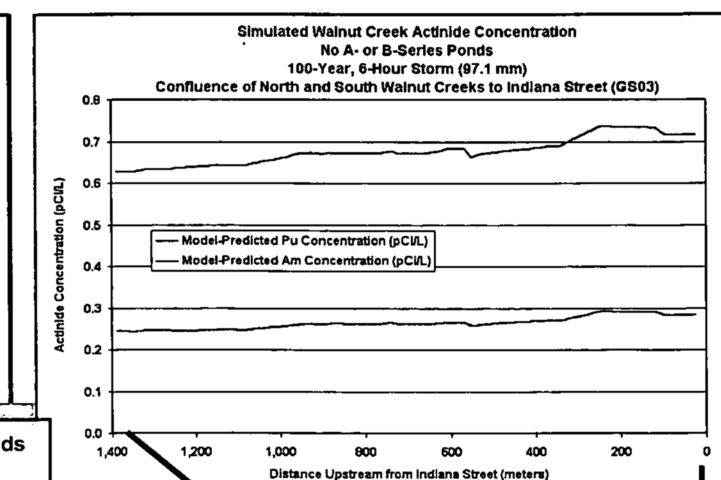


Estimated Actinide Yields at Indiana Street

Pu = 1.49E+08 pCi
Am = 5.14E+07 pCi

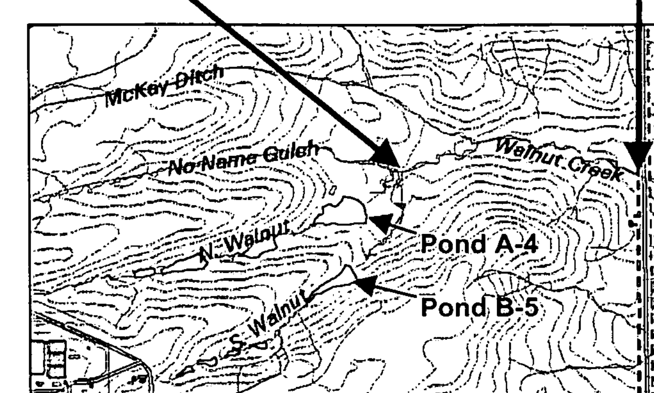
Walnut Creek: No Ponds Remain





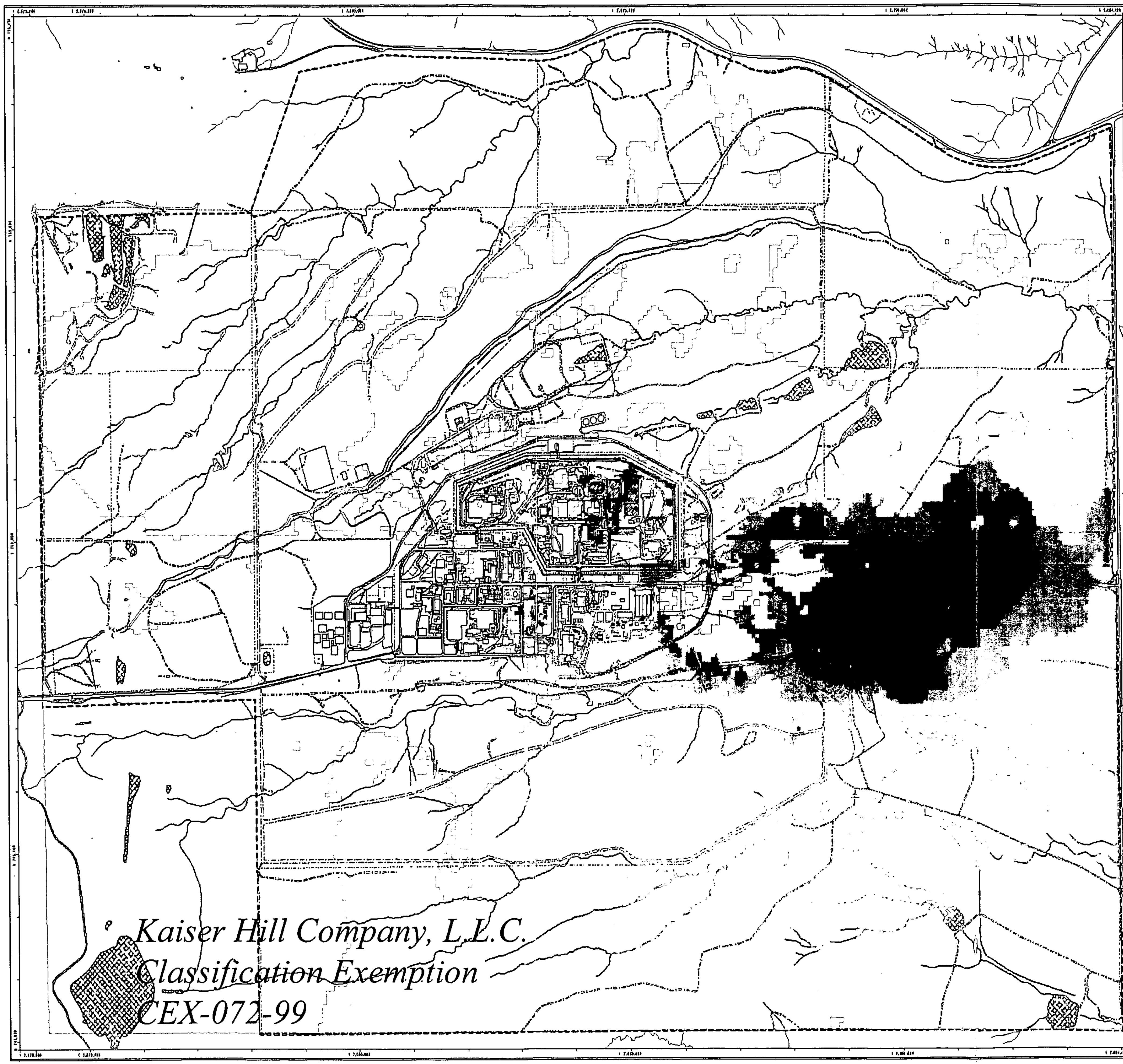
Estimated Actinide Yields at Indiana Street

Pu = 1.80E+08 pCi
Am = 7.17E+07 pCi



Lower Walnut Creek Location Reference

127



Kaiser Hill Company, L.L.C.
Classification Exemption
CEX-072-99

Pu-239 Isoplot (pCi/g)

(1999 Kriging Analysis Modified with road sample data collected 5/17/01)

EXPLANATION

- < = 0.1
- > 0.1 and < = 1.0
- > 1.0 and < = 5.0
- > 5.0 and < = 10.0
- > 10.0 and < = 25.0
- > 25.0 and < = 100.0
- > 100.0 and < = 252.0
- > 252.0 and < = 1429.0
- > 1429.0 and < = 10000.0
- > 10000.0

Standard Map Features

- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:

Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

Data Source:
1999 Kriging Analysis performed by Jeff Myers (The Washington Group, 303-843-3221). Edited data provided by Greg Wetherbee (Wright Water Engineers, 303-480-1700).

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

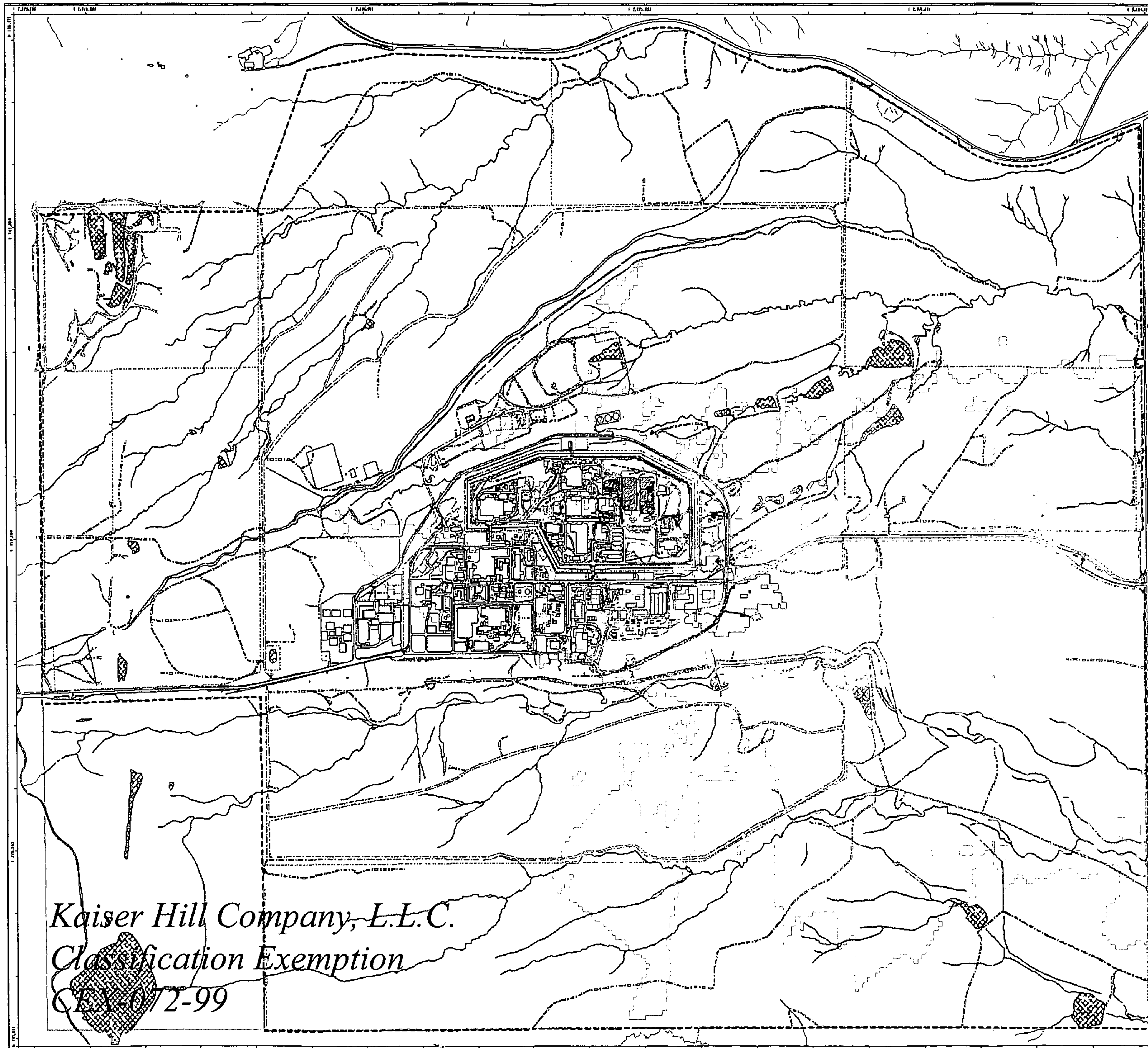
GIS Dept. 303-966-7707

MAP ID: 01-0669/pu_rd_resample.aml

June 25, 2001

NT_Svr h:/projects/fy2001/01-0669/pu_rd_resample.aml

171



Am-241 Isoplot (pCi/g)

(1999 Kriging Analysis Modified with road sample data collected 5/17/01)

EXPLANATION

- < = 0.1
- > 0.1 and < = 1.0
- > 1.0 and < = 5.0
- > 5.0 and < = 10.0
- > 10.0 and < = 38.0
- > 38.0 and < = 215.0
- > 215.0 and < = 500.0
- > 500.0

Standard Map Features

- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

Data Source:
1999 Kriging Analysis performed by Jeff Myers (The Washington Group, 303-843-2221).
Edited data provided by Greg Wetherbee (Wright Water Engineers, 303-480-1700).

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

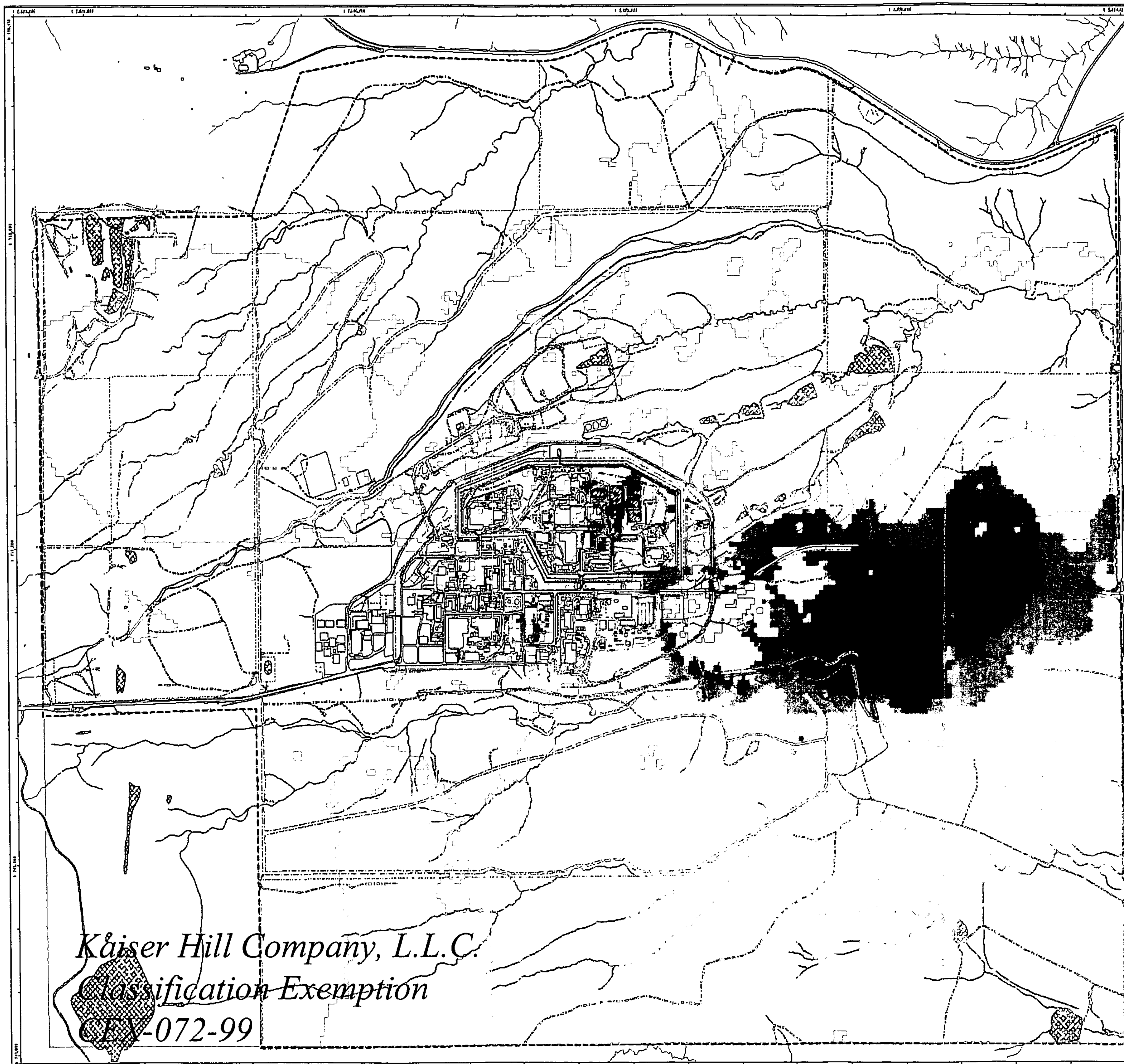
U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

172

Pu-239 Isoplot (pCi/g)

(1999 Kriging Analysis Edited for Simulated Road Regrading and Revegetation)



Kaiser Hill Company, L.L.C.
Classification Exemption
CEX-072-99

EXPLANATION

- < = 0.1
- > 0.1 and < = 1.0
- > 1.0 and < = 5.0
- > 5.0 and < = 10.0
- > 10.0 and < = 25.0
- > 25.0 and < = 100.0
- > 100.0 and < = 252.0
- > 252.0 and < = 1429.0
- > 1429.0 and < = 10000.0
- > 10000.0

Standard Map Features

- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:

Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

Data Source:

1999 Kriging Analysis performed by Jeff Myers (The Washington Group, 303-843-3221). Edited data provided by Greg Wetherbee (Wright Water Engineers, 303-480-1700).

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy

Rocky Flats Environmental Technology Site

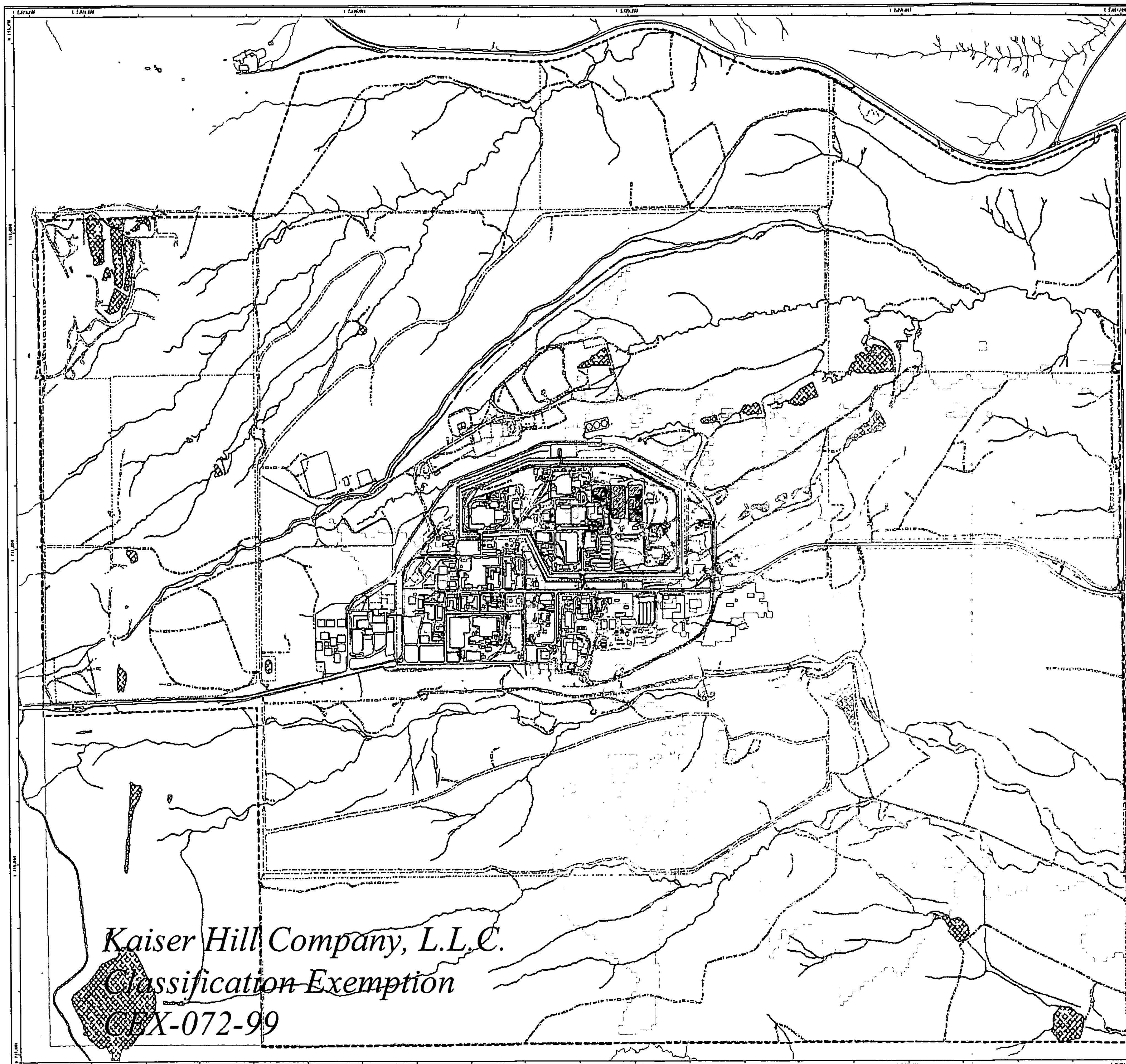
GIS Dept. 303-966-7707

MAP ID: 01-0834/pu_rd_reveg.aml

June 18, 2001

NT_Svr h:/projects/fy2001/01-0834/pu_rd_reveg.aml

173



Am-241 Isoplot (pCi/g)

(1999 Kriging Analysis Edited for Simulated Road Regrading and Revegetation)

EXPLANATION

- < = 0.1
- > 0.1 and < = 1.0
- > 1.0 and < = 5.0
- > 5.0 and < = 10.0
- > 10.0 and < = 38.0
- > 38.0 and < = 215.0
- > 215.0 and < = 500.0
- > 500.0

Standard Map Features

- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

Data Source:
1999 Kriging Analysis performed by Jeff Myers (The Washington Group, 303-843-3721).
Edited data provided by Greg Wetherbee (Wright Water Engineers, 303-480-1700).

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

NT_Svr h:/projects/fy2001/01-0684/am_rd_reveg.aml

174

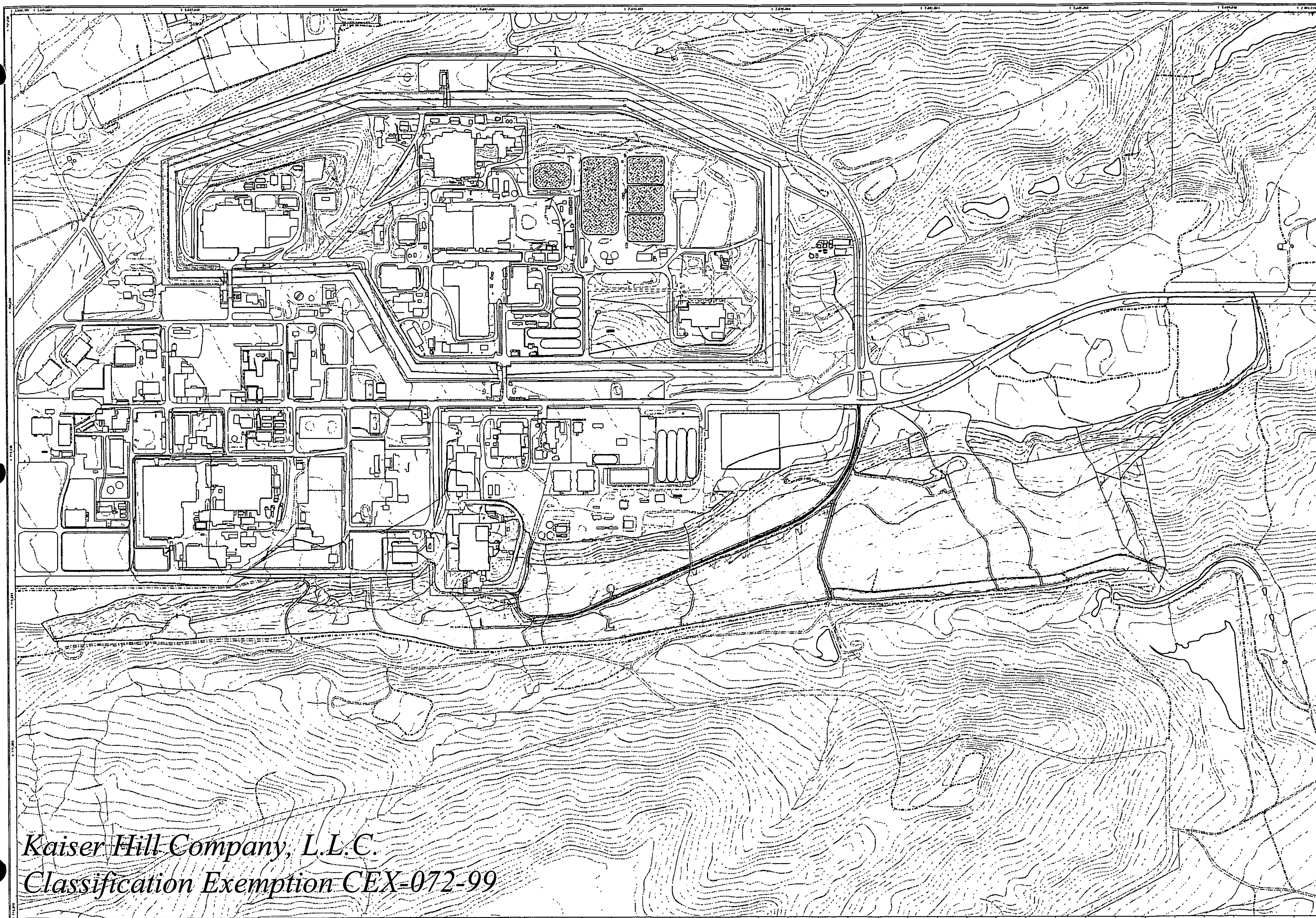


Figure 20

100-Year Event Erosion Map
South Interceptor Ditch (SID)

EXPLANATION

- > 0.400 Kg/m2 (0.737 Lbs/yd2) Deposition
- 0.200 Kg/m2 (0.369 Lbs/yd2) Deposition
- 0.020 Kg/m2 (0.037 Lbs/yd2) Deposition
- No Deposition or Detachment
- 0.010 Kg/m2 (0.018 Lbs/yd2) Detachment
- 0.025 Kg/m2 (0.046 Lbs/yd2) Detachment
- 0.050 Kg/m2 (0.092 Lbs/yd2) Detachment
- 0.100 Kg/m2 (0.184 Lbs/yd2) Detachment
- 0.150 Kg/m2 (0.276 Lbs/yd2) Detachment
- 0.200 Kg/m2 (0.369 Lbs/yd2) Detachment
- 0.250 Kg/m2 (0.461 Lbs/yd2) Detachment
- 0.300 Kg/m2 (0.553 Lbs/yd2) Detachment
- 0.350 Kg/m2 (0.645 Lbs/yd2) Detachment
- Road Detachment

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (5-Foot)
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudson (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. DEM post-processing performed by MK, Winter 1997.
Data Source:
Erosion data - Approved by Win Chromec (RMRS, 303-966-4535).

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by: DynCorp THE ART OF TECHNOLOGY

Prepared for: KAISER-HILL COMPANY

MAP ID: 01-0842/sid_erosion_100yr.aml

August 14, 2001

NT Svr o:/projects/fy2001/01-0842/sid erosion 100yr.aml

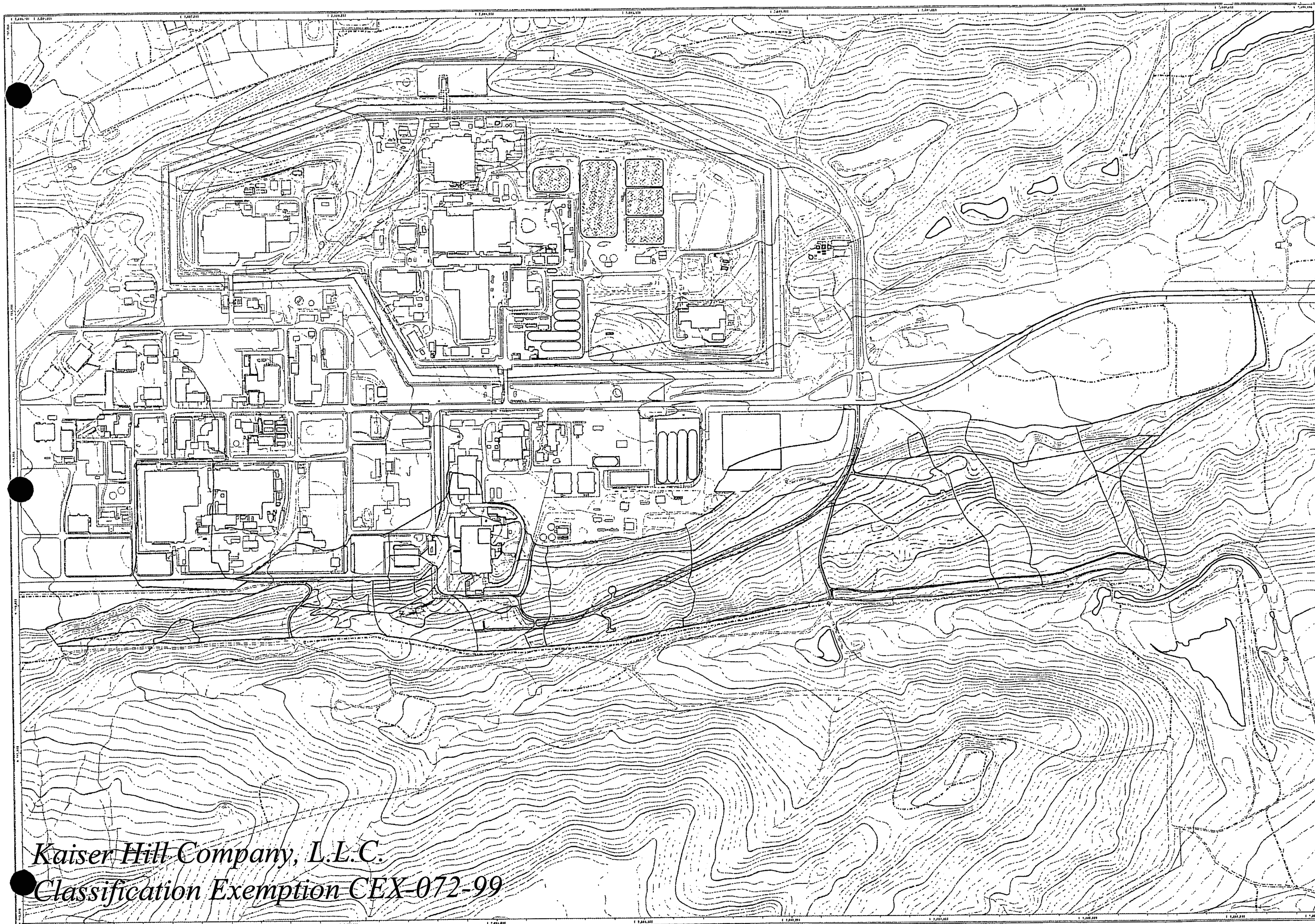
Kaiser Hill Company, L.L.C.
Classification Exemption CEX-072-99

175

Figure 22

35 mm Event Erosion Map

South Interceptor Ditch (SID)



EXPLANATION

- > 0.400 Kg/m2 (0.737 Lbs/yd2) Deposition
- 0.200 Kg/m2 (0.369 Lbs/yd2) Deposition
- 0.020 Kg/m2 (0.037 Lbs/yd2) Deposition
- No Deposition or Detachment
- 0.010 Kg/m2 (0.018 Lbs/yd2) Detachment
- 0.025 Kg/m2 (0.046 Lbs/yd2) Detachment
- 0.050 Kg/m2 (0.092 Lbs/yd2) Detachment
- 0.100 Kg/m2 (0.184 Lbs/yd2) Detachment
- 0.150 Kg/m2 (0.276 Lbs/yd2) Detachment
- 0.200 Kg/m2 (0.369 Lbs/yd2) Detachment
- 0.250 Kg/m2 (0.461 Lbs/yd2) Detachment
- 0.300 Kg/m2 (0.553 Lbs/yd2) Detachment
- 0.350 Kg/m2 (0.646 Lbs/yd2) Detachment
- Road Detachment

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (5-Foot)
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DSM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution. DSM post-processing performed by MK, Winter 1997.

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by: DynCorp THE ART OF TECHNOLOGY

Prepared for: KAISER-HILL COMPANY

MAP ID: 01-0846/sid_erosion_35mm.aml

August 16, 2001

NT Svr o:/projects/fy2001/01-0846/sid erosion 35mm.aml

176

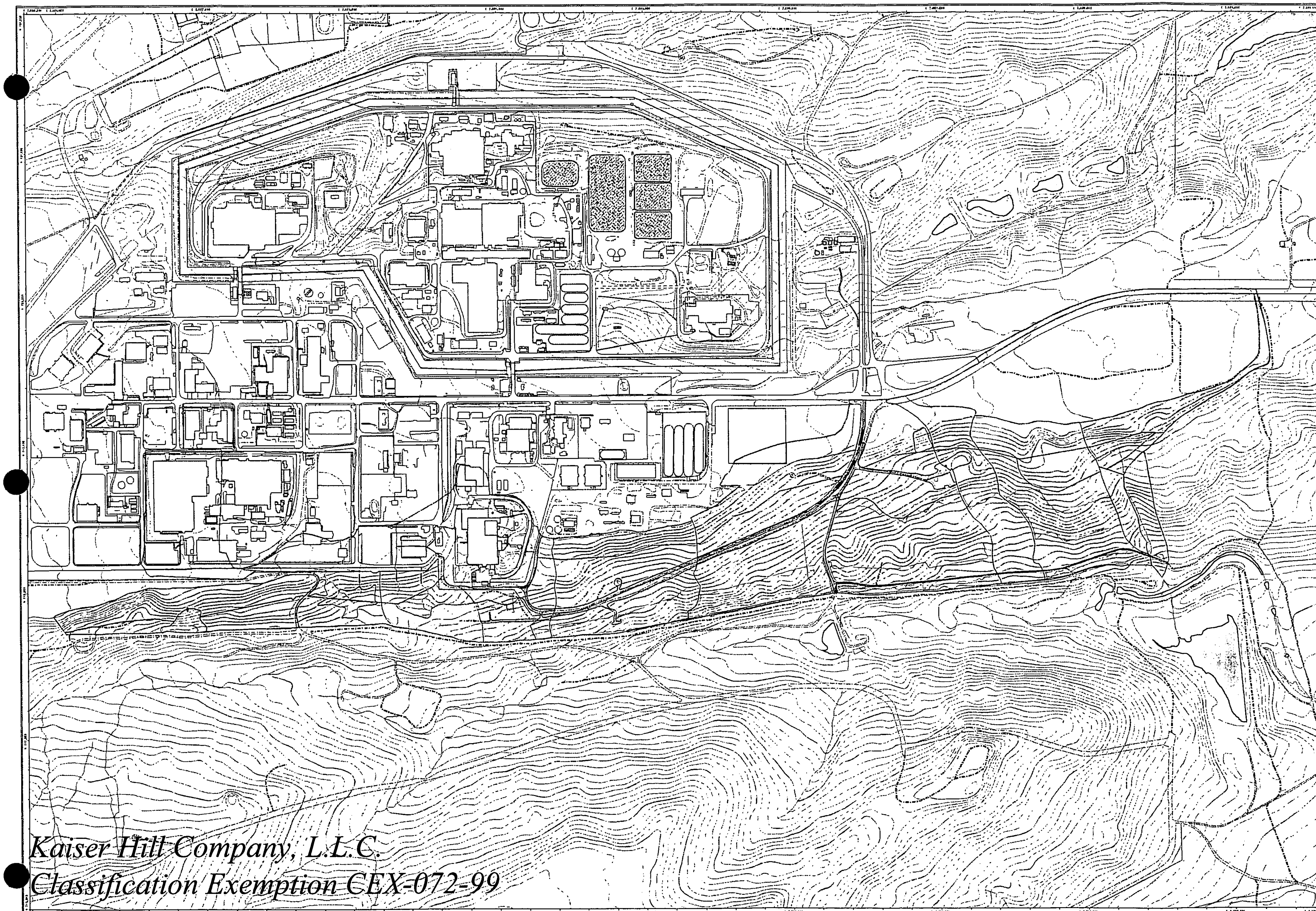


Figure 23

2-Hour Event Erosion Map

South Interceptor Ditch (SID)

EXPLANATION

- > 0.400 Kg/m2 (0.737 Lbs/yd2) Deposition
- 0.200 Kg/m2 (0.369 Lbs/yd2) Deposition
- 0.020 Kg/m2 (0.037 Lbs/yd2) Deposition
- No Deposition or Detachment
- 0.010 Kg/m2 (0.018 Lbs/yd2) Detachment
- 0.025 Kg/m2 (0.046 Lbs/yd2) Detachment
- 0.050 Kg/m2 (0.092 Lbs/yd2) Detachment
- 0.100 Kg/m2 (0.184 Lbs/yd2) Detachment
- 0.150 Kg/m2 (0.276 Lbs/yd2) Detachment
- 0.200 Kg/m2 (0.369 Lbs/yd2) Detachment
- 0.250 Kg/m2 (0.461 Lbs/yd2) Detachment
- 0.300 Kg/m2 (0.553 Lbs/yd2) Detachment
- 0.350 Kg/m2 (0.645 Lbs/yd2) Detachment
- Road Detachment

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (5-Foot)
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution. DEM post-processing performed by MK, Winter 1997.
Data Source:
Erosion data - Approved by Win Chromec (RMRS, 303-966-4535).

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by:
DynCorp
THE ART OF TECHNOLOGY

Prepared for:
KAISER-HILL COMPANY

MAP ID: 01-0844/sid_erosion_2hr.aml

August 14, 2001

NT Svr o:/projects/fy2001/01-0844/sid erosion 2hr.aml

177

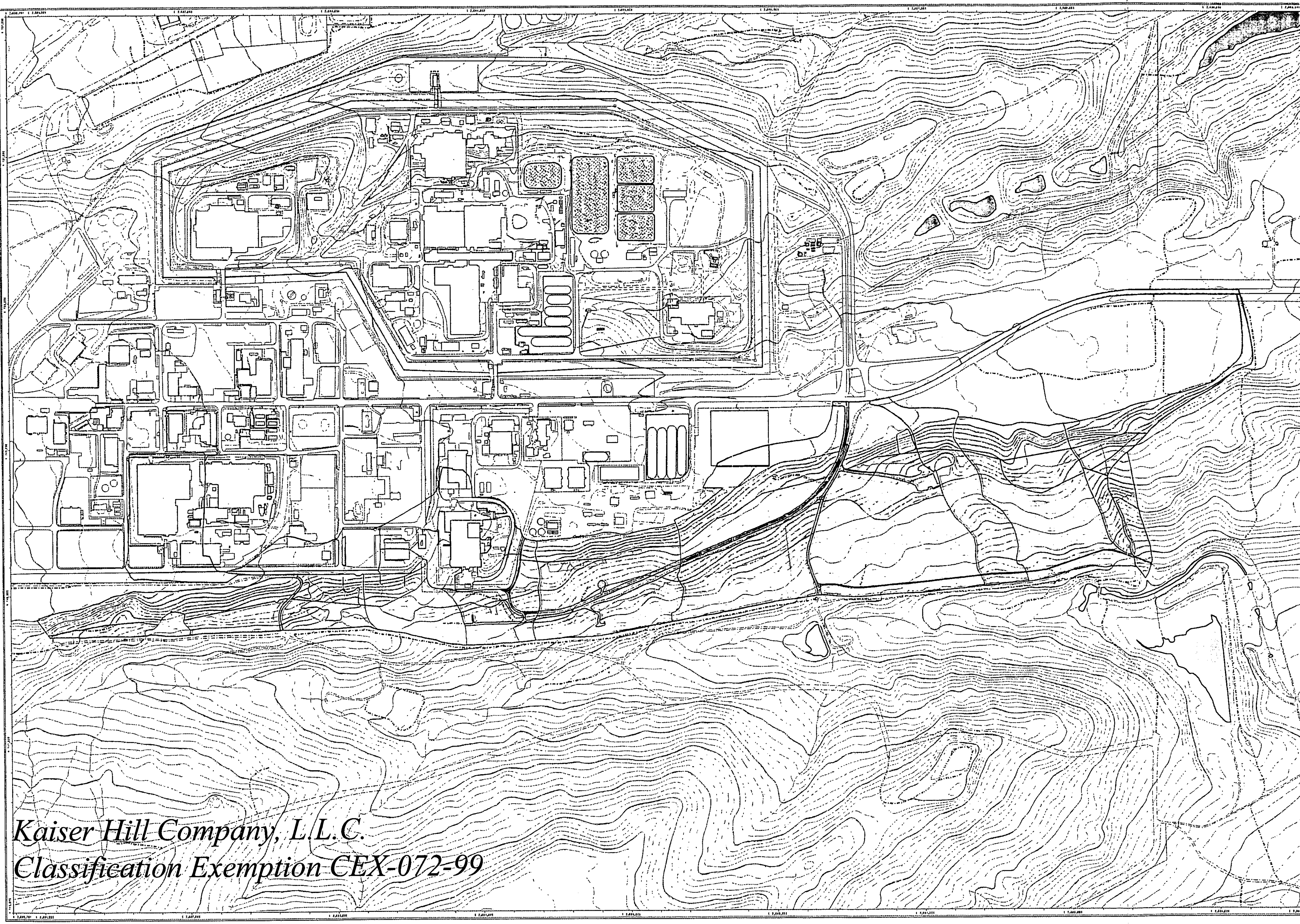


Figure 24

2-Year Event Erosion Map

South Interceptor Ditch (SID)

EXPLANATION

- > 0.400 Kg/m2 (0.737 Lbs/yd2) Deposition
- 0.200 Kg/m2 (0.369 Lbs/yd2) Deposition
- 0.020 Kg/m2 (0.037 Lbs/yd2) Deposition
- No Deposition or Detachment
- 0.010 Kg/m2 (0.018 Lbs/yd2) Detachment
- 0.025 Kg/m2 (0.046 Lbs/yd2) Detachment
- 0.050 Kg/m2 (0.092 Lbs/yd2) Detachment
- 0.100 Kg/m2 (0.184 Lbs/yd2) Detachment
- 0.150 Kg/m2 (0.276 Lbs/yd2) Detachment
- 0.200 Kg/m2 (0.369 Lbs/yd2) Detachment
- 0.250 Kg/m2 (0.461 Lbs/yd2) Detachment
- 0.300 Kg/m2 (0.553 Lbs/yd2) Detachment
- 0.350 Kg/m2 (0.645 Lbs/yd2) Detachment
- Road Detachment

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (5-Foot)
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudson (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. DEM post-processing performed by MK, Winter 1997.
Data Source:
Erosion data - Approved by Win Chromec (RMRS, 303-966-4535).

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by: DynCorp THE ART OF TECHNOLOGY

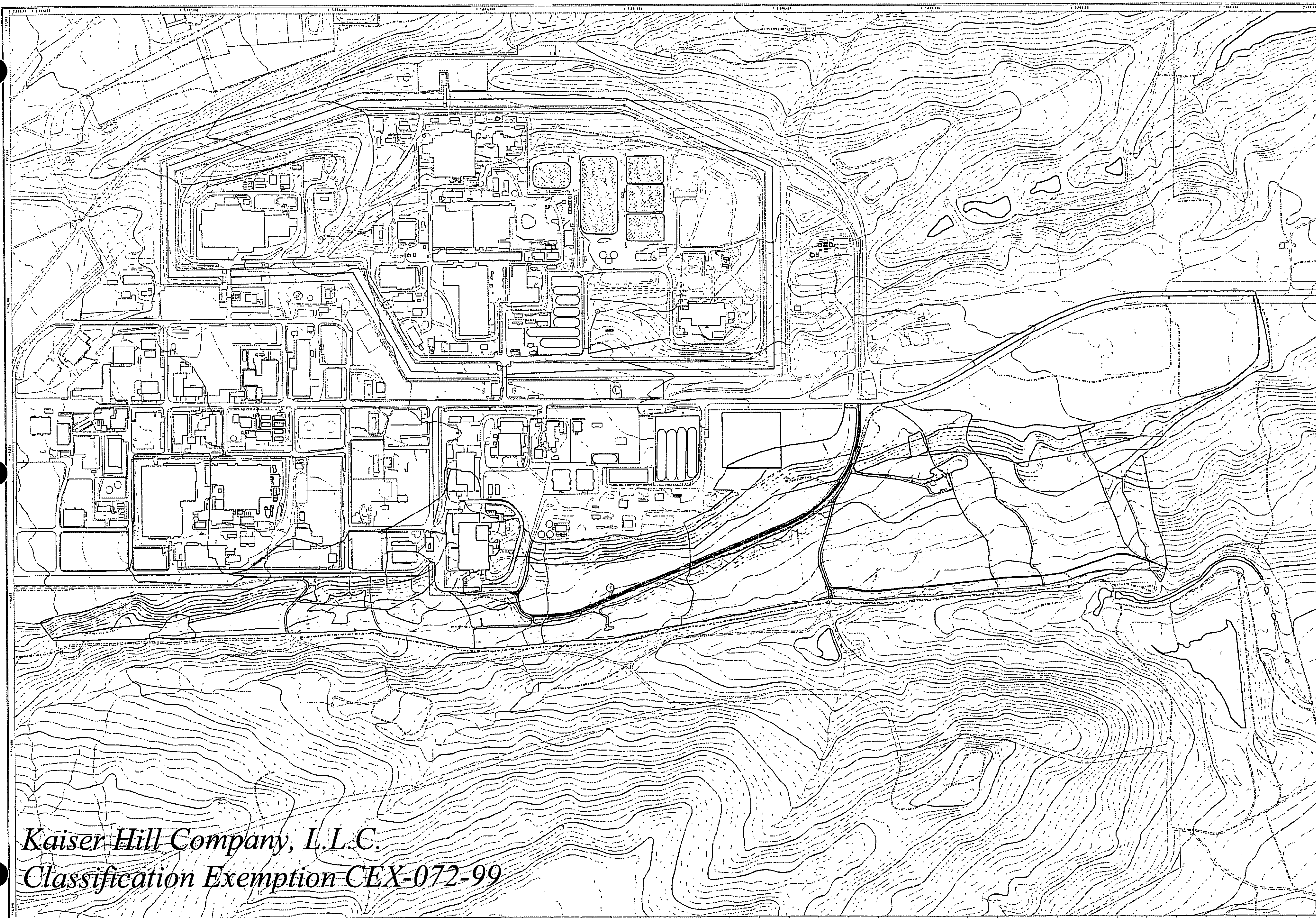
Prepared for: KAISER-HILL COMPANY

MAP ID: 01-0845/sid_erosion_2yr.aml

August 14, 2001

Kaiser Hill Company, L.L.C.
Classification Exemption CEX-072-99

178



Kaiser Hill Company, L.L.C.
Classification Exemption CEX-072-99

Figure 25
10-Year Event Erosion Map
South Interceptor Ditch (SID)

EXPLANATION

- > 0.400 Kg/m2 (0.737 Lbs/yd2) Deposition
- 0.200 Kg/m2 (0.368 Lbs/yd2) Deposition
- 0.020 Kg/m2 (0.037 Lbs/yd2) Deposition
- No Deposition or Detachment
- 0.010 Kg/m2 (0.018 Lbs/yd2) Detachment
- 0.025 Kg/m2 (0.046 Lbs/yd2) Detachment
- 0.050 Kg/m2 (0.092 Lbs/yd2) Detachment
- 0.100 Kg/m2 (0.184 Lbs/yd2) Detachment
- 0.150 Kg/m2 (0.276 Lbs/yd2) Detachment
- 0.200 Kg/m2 (0.368 Lbs/yd2) Detachment
- 0.250 Kg/m2 (0.461 Lbs/yd2) Detachment
- 0.300 Kg/m2 (0.553 Lbs/yd2) Detachment
- 0.350 Kg/m2 (0.645 Lbs/yd2) Detachment
- Road Detachment

Standard Map Features

- Buildings and other structures
- Solar Evaporation Ponds (SEP)
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences and other barriers
- Contour (5-Foot)
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95
Topology (contours) were derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~ 10 meter resolution. DEM post-processing performed by MK, Winter 1997.
Data Source:
Erosion data - Approved by Win Chromec (RMRS, 303-966-4535).

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

Prepared by: DynCorp THE ART OF TECHNOLOGY

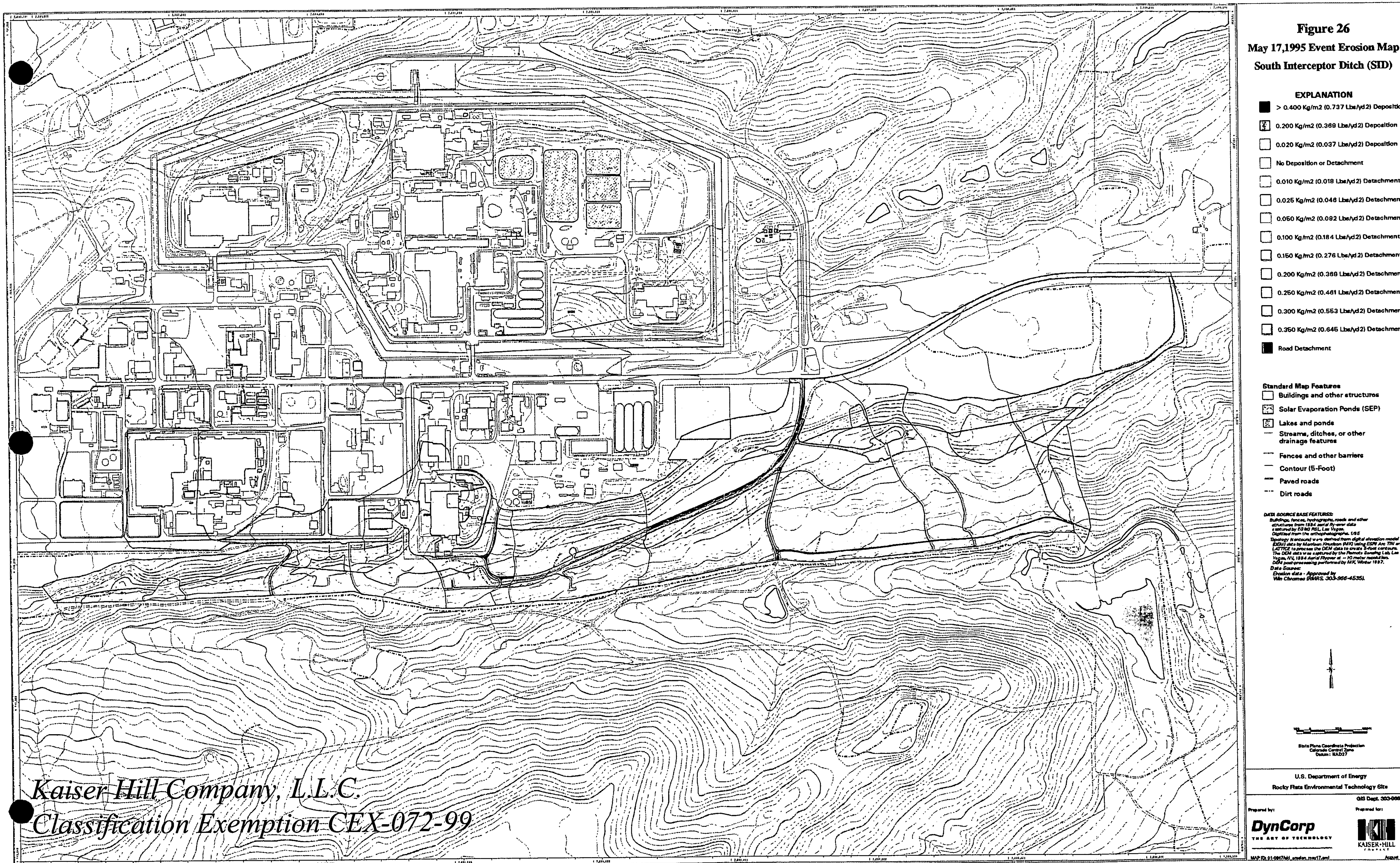
Prepared for: KAISER-HILL COMPANY

MAP ID: 01-0843/sid_erosion_10yr.aml

August 14, 2001

NT Svr o:/projects/fy2001/01-0843/sid erosion 10yr.aml

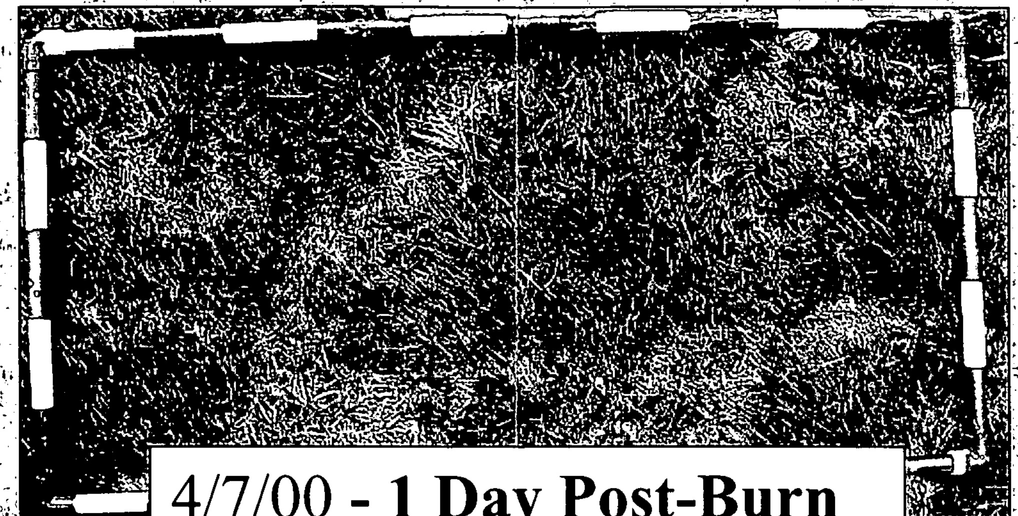
Figure 26
May 17,1995 Event Erosion Map
South Interceptor Ditch (SID)



Kaiser-Hill Company, L.L.C.
Classification Exemption CEX-072-99

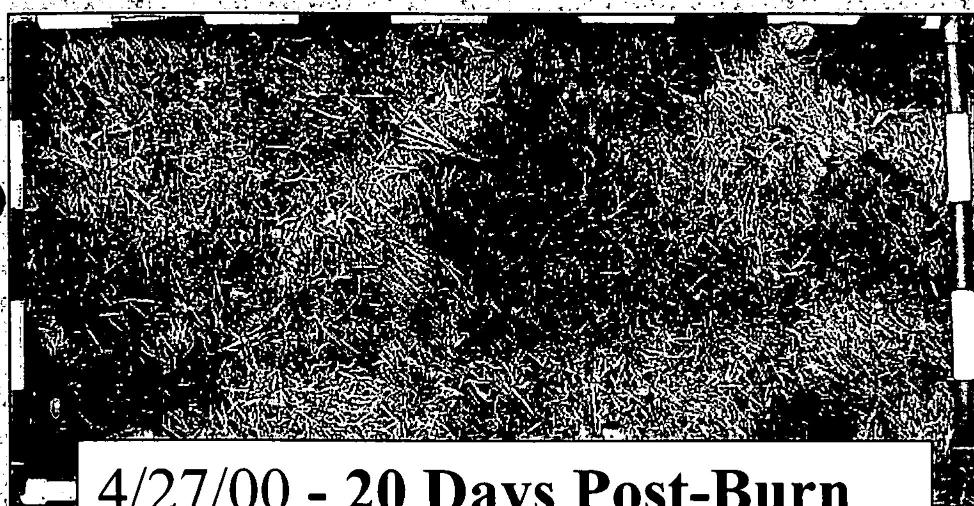
Figure 23. Time Series of Ground Surface in 2000 Prescribed Burn Area at the Site

3/13/00 - **Before Burn**



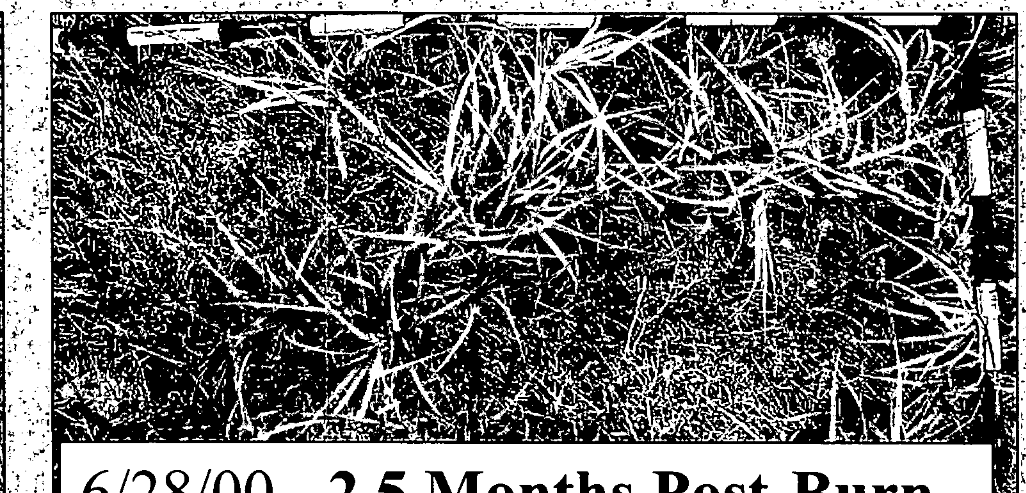
4/7/00 - **1 Day Post-Burn**

4/17/00 - **11 Days Post-Burn**



4/27/00 - **20 Days Post-Burn**

5/22/00 - **1.5 Months Post-Burn**



6/28/00 - **2.5 Months Post-Burn**

8/10/00 - **4 Months Post-Burn**

9/27/00 - **5.5 Months Post-Burn**

Photos Provided By

Jody Nelson, RFETS Ecology Group

Kaiser Hill Company, L.L.C.

Classification Exemption CEX-105-01

PLATE 1

Streambed & Channel Characteristics & Pu-239,240 in Streambed Sediments along Woman Creek

West Tile

Kaiser Hill Company, L.L.C.

Classification Exemption CEX-105-01

page 128 SW-A-004545

EXPLANATION

(Units = pCi/g)

- < 0.1
- > = 0.1 and < 0.5
- > = 0.5 and < 1.0
- > = 1.0 and < 5.0
- > = 5.0 and < 10.0
- > = 10.0 and < 100.0
- > = 100.0

Channel Type Category	Channel Type Description	Sediment Maximum Erodible Depth (cm)	Streambed Erodible Area (%)	Manning's n-Value Banks	Manning's n-Value Streambed
1	Cobbles and silt; woody vegetation in channel; willows and leadplant on banks	1-1.5	20 - 40	0.07	0.06
2	Armored channel with cobbles, boulders, gravel; willows and shrubs on banks	0	0 - 5	0.07	0.035
3	Grass-lined channel; grass banks	1-1.5	0 - 5	0.06	0.045
4	Armored channel with cobbles, boulders, gravel; grass banks	0	0 - 5	0.06	0.045
5	Sandy, silty with some gravel; some non-cohesive sediment; willows and leadplant on banks	1-1.5	20 - 40	0.07	0.06
6	Silt, clay, and cobble bottom; cattail-lined; choked with tall vegetation	1-1.5	0 - 5	0.06	0.09
7	Silt bottom with tall vegetation in channel	2.5	25 - 40	0.05	0.09
8	Small gravel and silt with cobbles; undercut, slumping banks; brush and grass banks	1	50 - 80	0.075	0.03

Model Drainage Basin Boundaries

SED4#### FY00 Sediment Survey Sampling Location

Standard Map Features

- Lakes and ponds
- Streams, ditches, or other drainage features
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:

Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

Data Source:
Sediment data - Approved by Win Chromec (RMRS, 303-966-4536).

N

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy

Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

MAP ID: 01-0007/strbed-chan_char_pu.aml

June 27, 2001

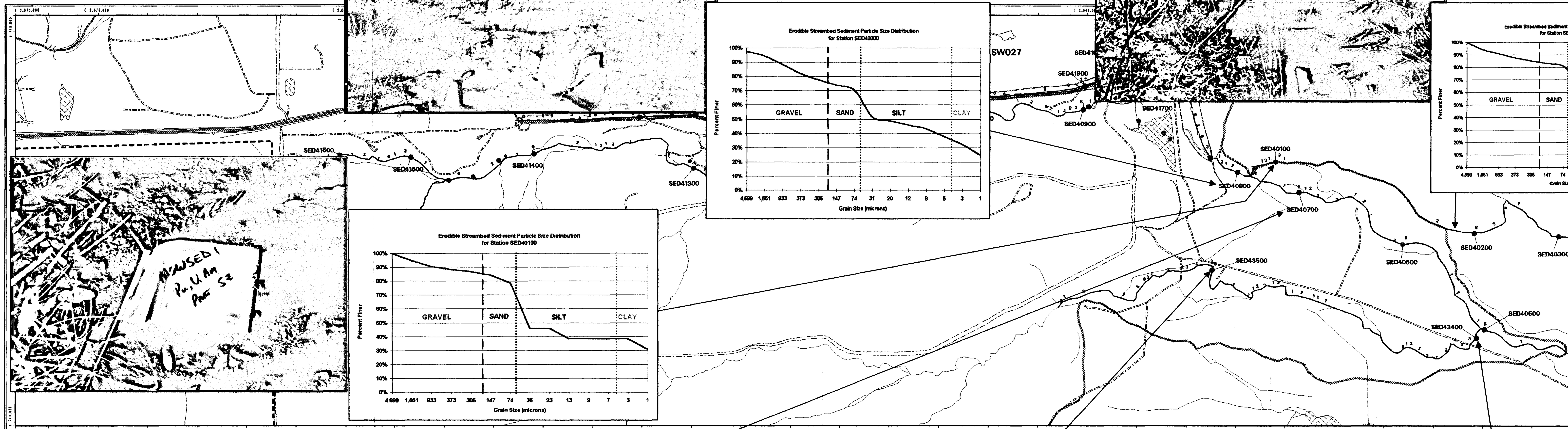


PLATE 2

Streambed & Channel Characteristics & Pu-239,240 in Streambed Sediments along Woman Creek

East Tile

pg 129 SW-A-004545

EXPLANATION

(Units = pCi/g)

- < 0.1
- > = 0.1 and < 0.5
- > = 0.5 and < 1.0
- > = 1.0 and < 5.0
- > = 5.0 and < 10.0
- > = 10.0 and < 100.0
- > = 100.0

Channel Type Category	Channel Type Description	Sediment Maximum Erodible Depth (cm)	Streambed Erodible Area (%)	Manning's n-Value Banks	Manning's n-Value Streambed
1	Cobbles and silt; woody vegetation in channel; willows and leadplant on banks	1-1.5	20 - 40	0.07	0.06
2	Armored channel with cobbles, boulders, gravel; willows and shrubs on banks	0	0 - 5	0.07	0.035
3	Grass-lined channel; grass banks	1-1.5	0 - 5	0.06	0.045
4	Armored channel with cobbles, boulders, gravel; grass banks	0	0 - 5	0.06	0.045
5	Sandy, silty with some gravel; some non-cohesive sediment; willows and leadplant on banks	1-1.5	20 - 40	0.07	0.06
6	Silt, clay, and cobble bottom; cattail-lined; choked with tall vegetation	1-1.5	0 - 5	0.06	0.09
7	Silt bottom with tall vegetation in channel	2.5	25 - 40	0.05	0.09
8	Small gravel and silt with cobbles; undercut, slumping banks; brush and grass banks	1	50 - 80	0.075	0.03

Model Drainage Basin Boundaries

SED4#### FY00 Sediment Survey Sampling Location

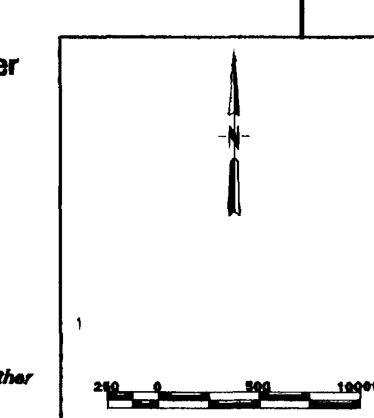
Standard Map Features

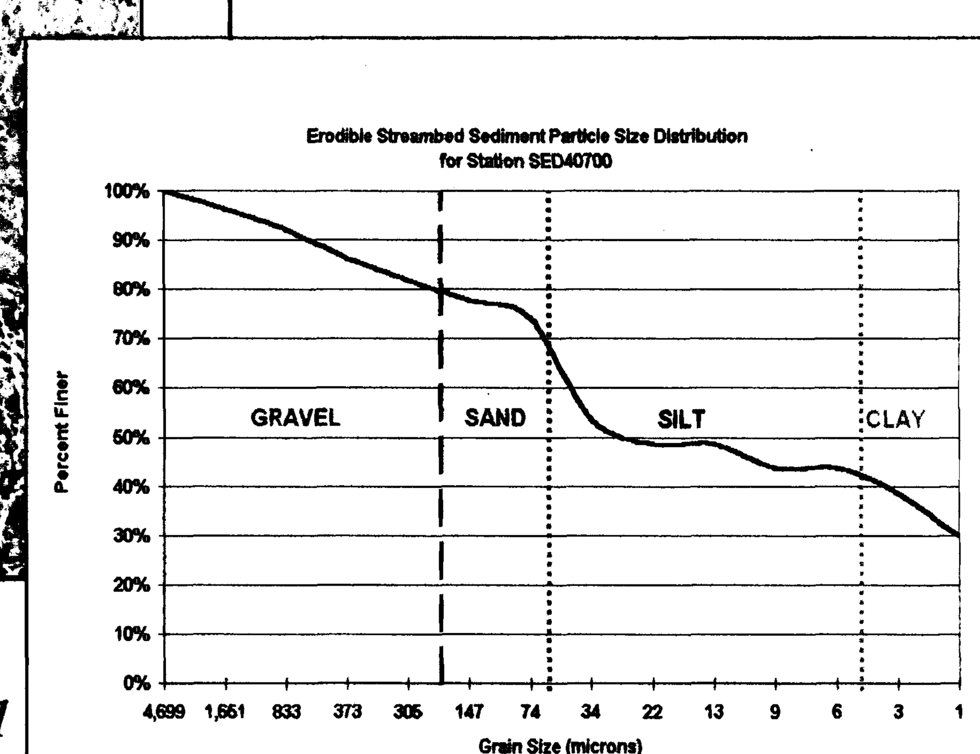
- Lakes and ponds
- Streams, ditches, or other drainage features
- Rocky Flats boundary
- Paved roads
- Dirt roads

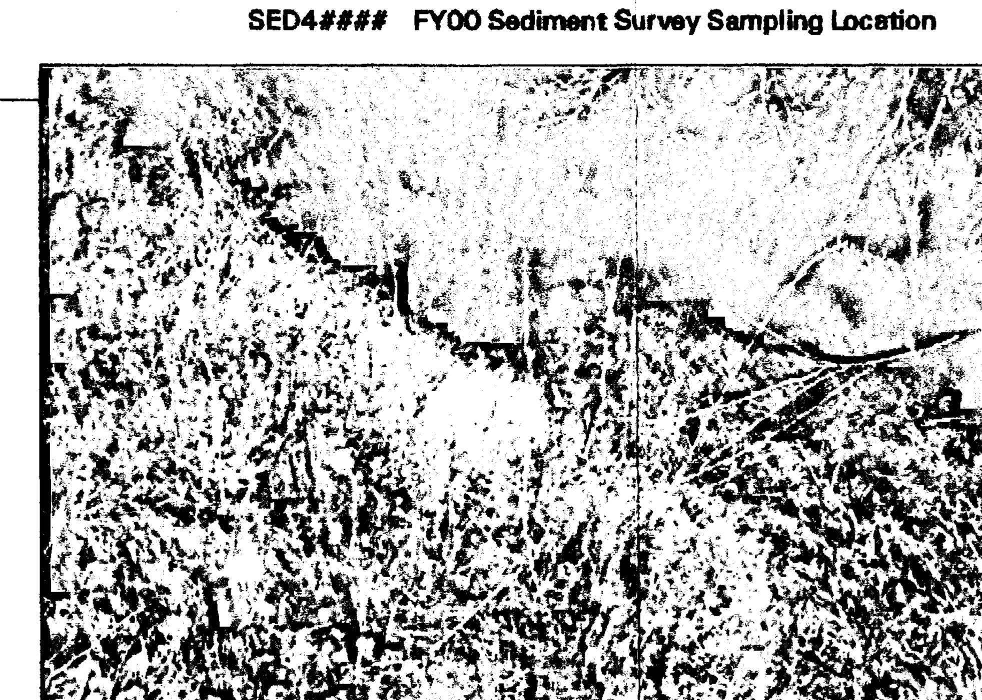
DATA SOURCE BASE FEATURES:

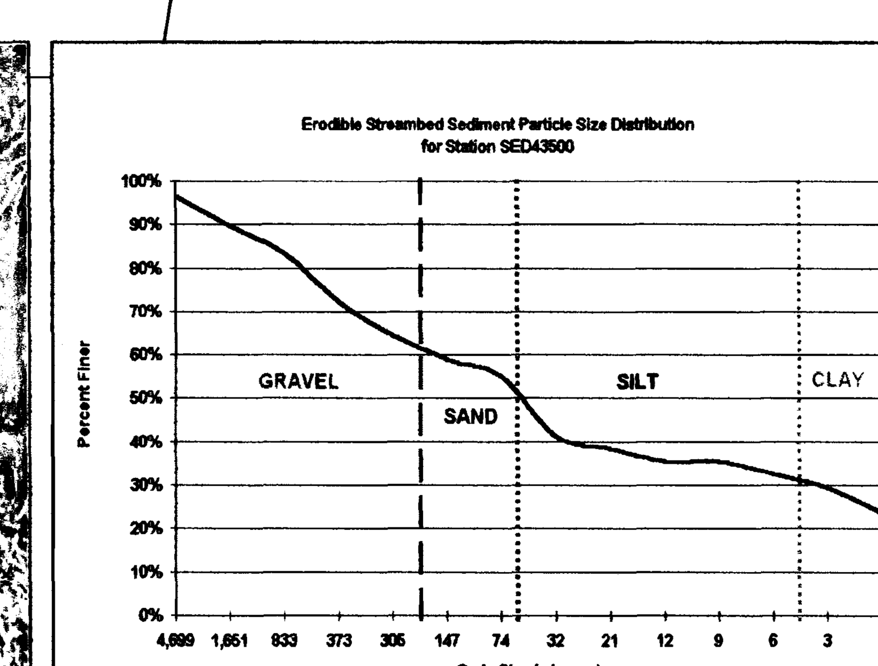
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

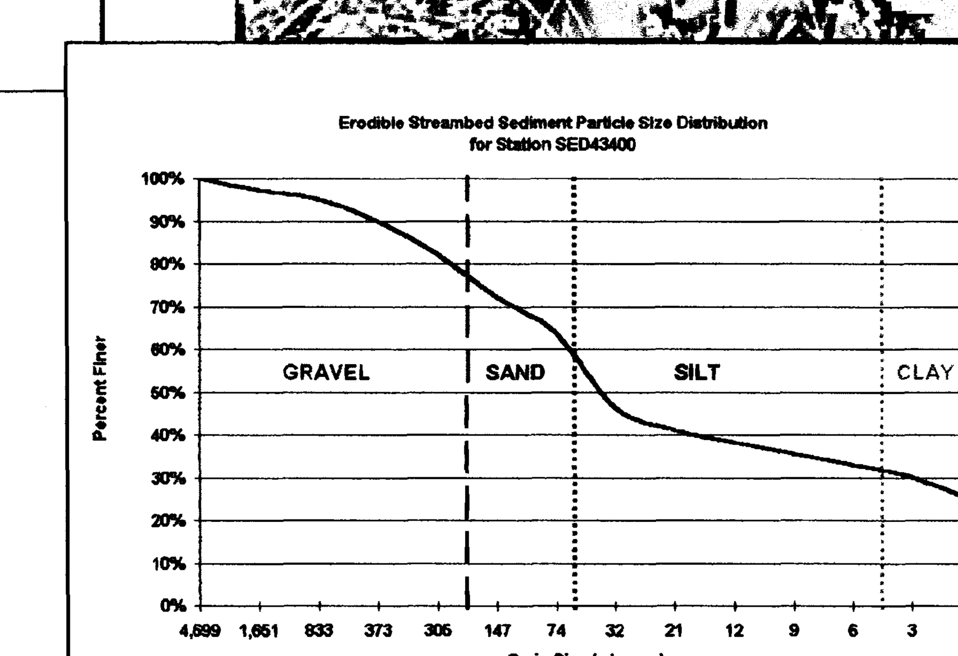
Data Source:
Sediment data - Approved by Win Chromec (RMRS, 303-966-4535).











Kaiser Hill Company, L.L.C.

Classification Exemption CEX-105-01

PLATE 3

Streambed & Channel Characteristics & Pu-239,240 in Streambed Sediments along SID

Kaiser Hill Company, L.L.C.

Classification Exemption CEX-105-01

EXPLANATION

(Units = pCi/g)

- < 0.1
- >= 0.1 and < 0.5
- >= 0.5 and < 1.0
- >= 1.0 and < 5.0
- >= 5.0 and < 10.0
- >= 10.0 and < 100.0
- >= 100.0

Channel Type Category	Channel Type Description	Sediment Maximum Erodible Depth (cm)	Streambed Erodible Area (%)	Manning's n-Value Banks	Manning's n-Value Streambed
1	Cobbles and silt; woody vegetation in channel; willows and leadplant on banks	1-1.5	20 - 40	0.07	0.06
2	Armored channel with cobbles, boulders, gravel; willows and shrubs on banks	0	0 - 5	0.07	0.035
3	Grass-lined channel; grass banks	1-1.5	0 - 5	0.06	0.045
4	Armored channel with cobbles, boulders, gravel; grass banks	0	0 - 5	0.06	0.045
5	Sandy, silty with some gravel; some non-cohesive sediment; willows and leadplant on banks	1-1.5	20 - 40	0.07	0.06
6	Silt, clay, and cobble bottom; cattail-lined; choked with tall vegetation	1-1.5	0 - 5	0.06	0.09
7	Silt bottom with tall vegetation in channel	2.5	25 - 40	0.05	0.09
8	Small gravel and silt with cobbles; undercut, slumping banks; brush and grass banks	1	50 - 80	0.075	0.03

Model Drainage Basin Boundaries

SED4#### FY00 Sediment Survey Sampling Location

Standard Map Features

- Lakes and ponds
- Streams, ditches, or other drainage features
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:

Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

Data Source:

Sediment data - Approved by Win Chromec (RMRS, 303-966-4535).

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy

Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

MAP ID: 01-0007/strbed-chan_char_pu.aml

June 27, 2001

pg 130 SW-A-004545

PLATE 4

Streambed & Channel Characteristics & Pu-239,240 in Streambed Sediments along Walnut Creek

South Tile

Kaiser Hill Company, L.L.C.

Classification Exemption CEX-105-01

page 131 SW-A-004545

EXPLANATION

(Units = pCi/g)

- < 0.1
- > = 0.1 and < 0.5
- > = 0.5 and < 1.0
- > = 1.0 and < 5.0
- > = 5.0 and < 10.0
- > = 10.0 and < 100.0
- > = 100.0

Channel Type Category	Channel Type Description	Sediment Maximum Erodible Depth (cm)	Streambed Erodible Area (%)	Manning's n-Value Banks	Manning's n-Value Streambed
1	Cobbles and silt; woody vegetation in channel; willows and leadplant on banks	1-1.5	20 - 40	0.07	0.06
2	Armored channel with cobbles, boulders, gravel; willows and shrubs on banks	0	0 - 5	0.07	0.035
3	Grass-lined channel; grass banks	1-1.5	0 - 5	0.06	0.045
4	Armored channel with cobbles, boulders, gravel; grass banks	0	0 - 5	0.06	0.045
5	Sandy, silty with some gravel; some non-cohesive sediment; willows and leadplant on banks	1-1.5	20 - 40	0.07	0.06
6	Silt, clay, and cobble bottom; cattail-lined; choked with tall vegetation	1-1.5	0 - 5	0.08	0.09
7	Silt bottom with tall vegetation in channel	2.5	25 - 40	0.05	0.09
8	Small gravel and silt with cobbles; undercut, slumping banks; brush and grass banks	1	50 - 80	0.075	0.03

Model Drainage Basin Boundaries

SED4#### FY00 Sediment Survey Sampling Location

Standard Map Features

- Lakes and ponds
- Streams, ditches, or other drainage features
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:

Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

Data Source:

Sediment data - Approved by Win Chromec (RMRS, 303-966-4535).

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy

Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

MAP ID: 01-0007/strbed-chan_char_pu.aml

June 27, 2001

PLATE 5

Streambed & Channel Characteristics & Pu-239,240 in Streambed Sediments along Walnut Creek

North Tile

Kaiser Hill Company, L.L.C.

Classification Exemption CEX-105-01

page 132 SW-A-004545

EXPLANATION

(Units = pCi/g)

- < 0.1
- >= 0.1 and < 0.5
- >= 0.5 and < 1.0
- >= 1.0 and < 5.0
- >= 5.0 and < 10.0
- >= 10.0 and < 100.0
- >= 100.0

Channel Type Category	Channel Type Description	Sediment Maximum Erodible Depth (cm)	Streambed Erodible Area (%)	Manning's n-Value Banks	Manning's n-Value Streambed
1	Cobbles and silt; woody vegetation in channel; willows and leadplant on banks	1-1.5	20 - 40	0.07	0.06
2	Armored channel with cobbles, boulders, gravel; willows and shrubs on banks	0	0 - 5	0.07	0.035
3	Grass-lined channel; grass banks	1-1.5	0 - 5	0.06	0.045
4	Armored channel with cobbles, boulders, gravel; grass banks	0	0 - 5	0.06	0.045
5	Sandy, silty with some gravel; some non-cohesive sediment; willows and leadplant on banks	1-1.5	20 - 40	0.07	0.06
6	Silt, clay, and cobble bottom; cattail-lined; choked with tall vegetation	1-1.5	0 - 5	0.06	0.09
7	Silt bottom with tall vegetation in channel	2.5	25 - 40	0.05	0.09
8	Small gravel and silt with cobbles; undercut, slumping banks; brush and grass banks	1	50 - 80	0.075	0.03

Model Drainage Basin Boundaries

SED4#### FY00 Sediment Survey Sampling Location

Standard Map Features

- Lakes and ponds
- Streams, ditches, or other drainage features
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:

Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas. Digitized from the orthophotographs. 1/95

Data Source: Sediment data - Approved by Win Chromec (RMRS, 303-966-4535).

N

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy

Rocky Flats Environmental Technology Site

GIS Dept. 303-966-7707

MAP ID: 01-0007/strbed-chan_char_pu.aml

June 27, 2001